

Hot Springs

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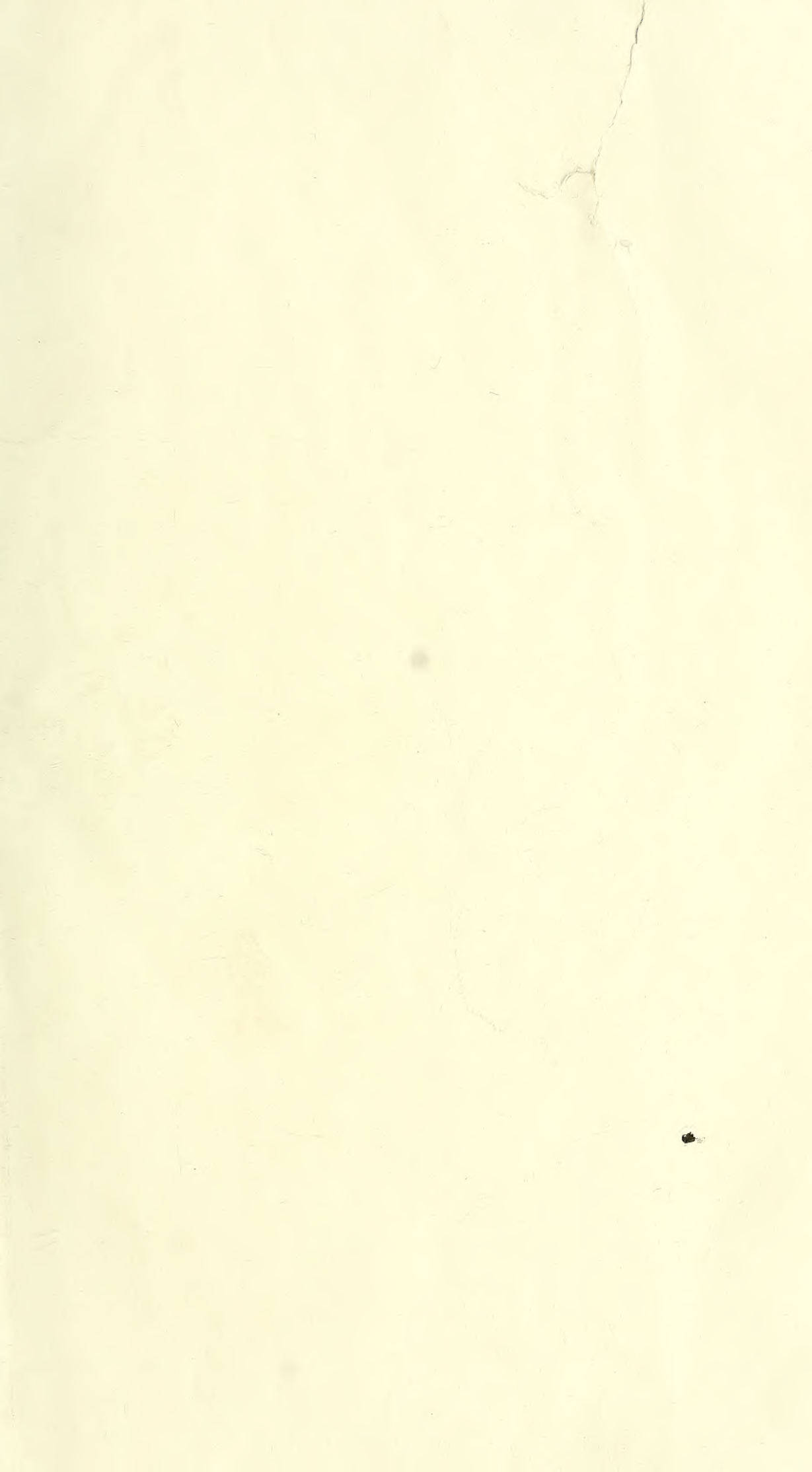
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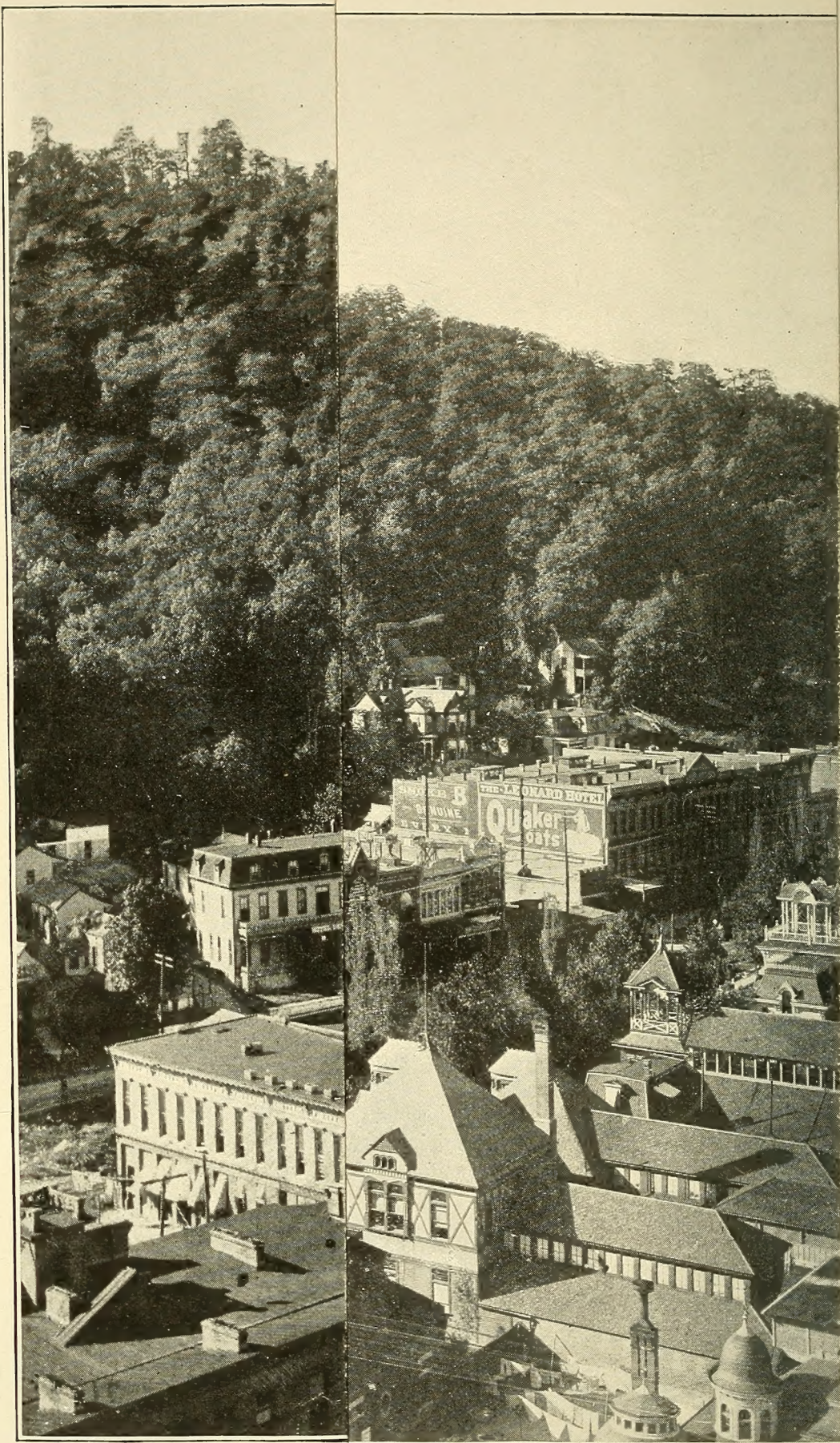


BIRD'S-EYE VIEW OF HOT SPRINGS; BUSINESS SECTION ON LEFT, BATH-HOUSE ROW IN CENTER, AND ARMY AND NAVY HOSPITAL ON RIGHT.









E VIEW OF HOT SPRINGS ; BUSINESS SECTION ON LEF



# THE HOT SPRINGS OF ARKANSAS.

## REPORT OF AN ANALYSIS OF THE WATERS OF THE HOT SPRINGS ON THE HOT SPRINGS RESERVATION, HOT SPRINGS, GARLAND COUNTY, ARK.,

WITH AN

ACCOUNT OF THE METHODS OF ANALYSIS EMPLOYED AND THE  
MEDICINAL VALUE OF VARIOUS SUBSTANCES USUALLY  
FOUND IN MINERAL WATER,

BY

J. K. HAYWOOD,

*In charge of Laboratory of Insecticides and Agricultural Waters, of the Bureau of  
Chemistry, U. S. Department of Agriculture,*

AND

## GEOLOGICAL SKETCH OF HOT SPRINGS, ARKANSAS.

BY

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*Geologist, United States Geological Survey.*

PREPARED UNDER THE SUPERVISION OF THE  
SECRETARY OF THE INTERIOR.

1902.

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1902.









## LETTER OF TRANSMITTAL.

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DEPARTMENT OF THE INTERIOR,  
*Washington, April 3, 1902.*

SIR: I am in receipt of Senate resolution of the 2d instant—

That the Secretary of the Interior be, and he is hereby, directed to forward to the Senate the reports, prepared under his direction, of analysis of the waters of the Hot Springs, on the Hot Springs Reservation, Arkansas, by Mr. J. K. Haywood, of the Bureau of Chemistry, Department of Agriculture, and geological sketch of Hot Springs Reservation by Prof. Walter H. Weed of the United States Geological Survey.

In response thereto, I have the honor to transmit herewith a copy of the report indicated in the foregoing resolution, together with the accompanying maps and illustrations.

Very respectfully,

E. A. HITCHCOCK,  
*Secretary.*

THE PRESIDENT PRO TEMPORE OF THE UNITED STATES SENATE.







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## CORRESPONDENCE.

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DEPARTMENT OF THE INTERIOR,  
*Washington, August 29, 1899.*

SIR: There are on the Hot Springs Reservation, Hot Springs, Ark., a number of hot springs the water from which is, under the supervision of this Department, supplied to certain bath houses for the benefit of the public. The waters of these springs are claimed to have medicinal qualities, and from the number of cures that have been effected from the use thereof it is believed to be true. No official analysis, however, has ever been made of the properties of these waters, and I therefore have the honor to request to be advised as to whether it will be practicable for an analysis of the waters of these hot springs to be made by the chemists of your Department.

Any expense that may be incurred in the matter will be defrayed from the Hot Springs Reservation fund. A copy of the last annual report of the superintendent of the Hot Springs Reservation is inclosed, in which will be found a list of the hot springs, their relative temperature, elevation, and character of the flow of the water therefrom.

Very respectfully,

THOS. RYAN,  
*Acting Secretary.*

The SECRETARY OF AGRICULTURE.

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DEPARTMENT OF AGRICULTURE,  
OFFICE OF THE SECRETARY,  
*Washington, D. C., September 9, 1899.*

SIR: In reply to your communication of September 2, I would say that I have directed Dr. H. W. Wiley, the Chief Chemist of the Department, to undertake the analyses of the waters from the Hot Springs of Arkansas, in the Government reservation.

I have the honor to be, sir,

Respectfully,

JAMES WILSON,  
*Secretary.*

The honorable the SECRETARY OF THE INTERIOR.

DEPARTMENT OF AGRICULTURE,  
OFFICE OF THE SECRETARY,  
*Washington, D. C., December 9, 1901.*

SIR: I have the honor to transmit herewith the report of the Chief of the Bureau of Chemistry on the results of the analyses of waters of the hot springs, in accordance with the request which you made of me August 29, 1900. The general scope of the work is fully set forth in the letter of introduction prepared by Dr. Wiley, and I trust that you will find the data of the experimental work, which was conducted under his direction by Mr. J. K. Haywood, satisfactory.

Respectfully,

JAMES WILSON,  
*Secretary.*

The SECRETARY OF THE INTERIOR.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,  
BUREAU OF CHEMISTRY,  
*Washington, D. C., December 9, 1901.*

SIR: I beg to transmit herewith the results of the work done in this Bureau in the examination of the waters of the Hot Springs of Arkansas. This work was undertaken in harmony with the request made to you by the Secretary of the Interior, and under the instructions which you gave me in acceding to that request.

After a careful preliminary study of the nature of the problems to be investigated, I, with your consent, detailed Mr. J. K. Haywood, one of my assistants and an expert in water analysis, for the purpose of undertaking the analyses desired. Mr. Haywood was given full instructions in regard to the character of the work which he was to perform, and in compliance with those instructions proceeded to Hot Springs, where he made the necessary study of the waters at the springs themselves. He also secured abundant samples of the waters for the examination which could be made in the laboratory of this Bureau.

Mr. Haywood has given in the following pages the results of his investigations, together with certain opinions in regard to the therapeutic values of the waters, which it is deemed advisable should accompany the report. In regard to these opinions it is only proper to say that they are not our own, but are based upon the authorities which are regarded as reliable in such matters. It must not be understood, however, that these opinions in regard to the therapeutic value of the waters have any official indorsement whatever from this Bureau. We have not made any experimental determinations of the healing qualities of the waters, nor have we studied their effects on invalids. These opinions are subject to correction or change, in the light of further investigations made by us or by other parties, and must not be accepted with too much consideration. The value of these thermal waters in certain chronic cases of disease is well established; but how this therapeutic action is secured is not a proper subject of investigation by this Bureau.



This report is a valuable contribution to our knowledge of thermal waters, and I believe it will be found thorough and accurate, representing the sum of our knowledge of these waters at the present time.

I have the honor to request that you transmit this bulletin to the honorable the Secretary of the Interior.

Respectfully,

H. W. WILEY,  
*Chief of Bureau of Chemistry.*

Hon. JAMES WILSON,  
*Secretary of Agriculture.*

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**THE CHEMICAL COMPOSITION OF THE WATERS OF THE HOT SPRINGS OF ARKANSAS, WITH AN ACCOUNT OF THE METHODS OF ANALYSIS EMPLOYED AND THE MEDICINAL VALUE OF VARIOUS SUBSTANCES USUALLY FOUND IN MINERAL WATERS.**

By J. K. HAYWOOD,

*In Charge of Laboratory of Insecticides and Agricultural Waters.*

[Analyses performed at the Bureau of Chemistry, United States Department of Agriculture, under the direction of H. W. Wiley, chief chemist.]

INTRODUCTION.

The Hot Springs of Arkansas are situated in Garland County immediately adjacent to Hot Springs City, on the western slope and at the base of Hot Springs Mountain, a spur of the Ozark Range. Originally there were said to have been seventy-one of these springs, but on account of improvements on the mountain, necessitating the merging of two or more springs into one, also by reason of the natural changes in the subterranean course of the water, this number has been reduced to forty-nine. Forty-four of these are either in use or can easily be used by making some slight improvements. Five rise from the bed of the creek situated at the base of the mountain, and are consequently lost in the cold water of the stream. Besides the hot springs mentioned above, there are two cold springs in close juxtaposition on the northern slope of the mountain.

In making the analyses of these waters, because of changes apt to take place in certain constituents on standing, some of the determinations were made directly on the ground within one hour after the samples had been taken. The determinations mentioned are nitrogen, oxygen, carbon dioxide (free and as bicarbonates), nitrites, nitrates, oxygen consuming capacity, and free and albuminoid ammonia. Besides this, 10-gallon samples of each spring were shipped to Washington, D. C., where determinations of the various mineral constituents were at once begun. Each day the temperature of the spring then under analysis was taken; finally at the end of the chemist's stay at Hot Springs the temperatures were retaken in a single day, as well as the flow of each spring.

The constituents determined in each of the 44 hot springs and in the 2 cold springs include the following:

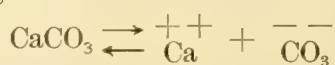
Oxygen, consuming capacity.	Chlorine.
Albuminoid ammonia.	Boric acid.
Free ammonia.	Phosphoric acid.
Lithium.	Nitric acid.
Sodium.	Nitrous acid.
Potassium.	Sulphuric acid.
Magnesium.	Silicic acid.
Calcium.	Carbonic acid.
Iron and aluminum.	Bicarbonic acid.
Manganese.	Nitrogen.
Arsenic.	Oxygen.
Iodine.	Hydrogen sulphide.
Bromine.	Total solids.

Besides these substances, the following were determined in spring No. 15 (Big Iron), which is not only the largest spring in the group but will serve as an example of all the other springs, since the chemical composition of all of them is so nearly alike:

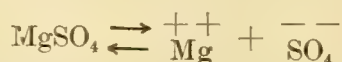
Barium.  
Strontium.  
Fluorine.

In reporting the results of analysis, the bases and acids are given in parts per million of the positive and negative ions, except in the case of silica, which, in the present state of our knowledge, we can only report as such, not going into the question of how much is present as the silicic acid ion and how much present as free silica. Iron and aluminum are always reported together, because of the great difficulty in separating such small amounts of the two as appear in these waters. Wherever iron and aluminum are involved in any calculation the whole is considered as iron and given an atomic weight of 56. This is doubtless practically correct, since a test of the residue from a large volume of one of the springs showed that the iron-aluminum precipitate consisted almost entirely of iron and contained aluminum, at the most, only in traces.

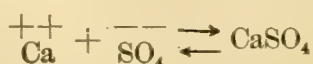
Because of the fact that these analyses will doubtless be referred to by many who have had no chemical training, the author has thought it best to combine the acids and bases in a hypothetical combination, thus reporting them as salts. That such a combination has no basis, in fact, is doubtless true, since we have every reason to believe that where various basic and acid ions are present in solution no base unites with any particular acid to the exclusion of all others, or vice versa, but that all possible combinations are formed, to at least some extent, of the various basic and acid ions present in solution. For example: Suppose we have calcium carbonate in solution. It partly dissociates into the positive and negative ions Ca and  $\text{CO}_3$  as follows:



Again, if magnesium sulphate is in solution it partly dissociates as follows:

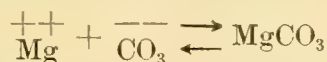


Now, if these two solutions are poured into each other, part of the calcium and sulphuric acid ions unite to form calcium sulphate, as follows:





and part of the magnesium and carbonic acid ions unite to form magnesium carbonate, as follows:



so that we have in solution not only the calcium carbonate, magnesium sulphate, and magnesium, calcium, carbonic acid, and sulphuric acid ions with which we started, but also some calcium sulphate and magnesium carbonate.

In calculating the above-mentioned hypothetical combination, sodium is joined to the nitrous and nitric acid ions; potassium to iodine and bromine; calcium to the phosphoric-acid ion and sodium to the metaboric-acid ion. Chlorine is assigned to the bases in the order  $\text{NH}_4$ , Li, K, Na; sulphuric-acid ion in the order  $\text{NH}_4$ , Li, K, Na, Mg, Ca, and the residual bases are joined to bicarbonic-acid ion in the order Na, Mg, Ca, Mn, Fe. In case the bicarbonic-acid ion is not present in large enough amounts to join with all the remaining bases, the residual calcium is joined to silica to form calcium silicate, and manganese and iron are calculated as  $\text{Mn}_3\text{O}_4$  and  $\text{Fe}_2\text{O}_3$ , respectively.

#### METHODS OF EXAMINATION.

**TEMPERATURE.**—The temperature of each spring was taken with an accurately standardized maximum thermometer on the date of the sanitary analysis of the water. Finally, the temperatures of all of the springs were taken in one day. It will be noticed that these temperatures sometimes vary quite a few degrees for the same spring. This seems to be due to two causes. In the first place the temperature of the spring as it issues from the earth varies slightly from time to time; secondly, the springs sometimes have quite large basins, so that we can not get the temperature just as the water issues from the earth, but must take it as influenced by a comparatively large body of water, which in turn has been cooled to some extent by standing in the air. When these springs have recently been drained the temperature is nearly the same as where they issue from the earth, but when the basin is full the temperature is quite a few degrees lower.

**FLOW.**—The flow of each spring was measured by observing the length of time taken to fill a vessel of known capacity from a pipe that drained the spring in question. In some cases such determinations could not be made, so the flow of the springs was estimated by comparing them with other springs of known flow. Such estimations were made by the head waterman of the reservation, Mr. Ed Hardin, who by long experience had arrived at such a point that he could come very near the correct figure.

**HYDROGEN SULPHIDE.**—The test for the presence of hydrogen sulphide was made both by boiling a sample of water and noticing the smell, and by passing the vapors over a piece of lead acetate paper. In a few cases, as a check, an actual determination of the hydrogen sulphide by the method given in Sutton's Volumetric Analysis was made. This is as follows:

About 0.5 c. c. of  $\frac{n}{10}$  iodine was measured into a 500 c. c. flask and the water under examination run in till the color of the iodine disappeared. Five c. c. of starch water was added and  $\frac{n}{10}$  iodine run in till the blue color appeared. The flask was then filled to the mark with

distilled water. The amount of water actually titrated was found by subtracting the sum of iodine, starch solution, and distilled water from 500 c. c. As an excess of iodine solution was required to produce the blue color a correction was applied by making 5 c. c. of starch solution up to 500 c. c. with distilled water and adding  $\frac{n}{10}$  iodine until the color of the solution was just as blue as that in the actual determination. This figure subtracted from the first figure would give the number of c. c. of  $\frac{n}{10}$  iodine used by the hydrogen sulphide. In every case tried the correction was just equal to the original figure, and in neither of the other tests was hydrogen sulphide found to be present in any of the springs.

NITROGEN AND OXYGEN were determined by making use of the Tiemann and Preusse modification of Reichhardt's apparatus, the description of which is here taken from Hempel's Gas Analysis (translated by L. M. Dennis, Cornell University):

This consists of two flasks A and B (Fig. 1) each of about 1 liter capacity and connected by tubes with the gas collector C. The flask A is fitted with a perforated rubber stopper in which is inserted the glass tube *a* bent at a right angle and ending flush with the lower surface of the stopper; *a* is joined by a piece of rubber tubing to the tube *bc*, which in turn connects with the gas collector C. C is held by a clamp, has a diameter of 30 mm., is about 560 mm. long, and at the upper end is drawn out to a short, narrow tube, which can be closed with the rubber tube and pinchcock *g*. In the lower end of C is a rubber stopper with two holes through one of which the tube *bc*, projecting about 280 mm. into C, is inserted. Through the other opening passes the tube *d*, which extends only slightly beyond the stopper and connects C with the flask B. B has a double bore rubber stopper carrying the tubes *e*, and *f*; *e* ends about 10 mm. above the bottom of the flask and above the stopper it is bent at a right angle and is connected with *d*. The tube *f*, which need not project below the stopper, carries a thin rubber tube X about 1 meter in length and provided with a mouthpiece. A pinchcock for closing the rubber between *a* and *b* is also needed.

The apparatus thus arranged is made ready for a determination by filling the flask B somewhat more than half full of boiled, distilled water and removing the flask A by slipping the tube *a* out of the rubber connection; then by blowing into the rubber tube X, water is driven over from the flask B into the gas collector C and the adjoining tubes until the air is wholly displaced. The rubber tubes at *b* and *g* are now closed with pinchcocks. The flask A is then filled to the brim with distilled water, the stopper is inserted, water being thereby driven into the tube *a* and the flask is again connected with *b*, the pinchcock being opened.

The water in B is now heated to gentle boiling, and that in A is allowed to boil somewhat more rapidly. The absorbed air is thus driven out and the gases dissolved in the water which is in A and C collect in the upper part of C from which they are removed by occasionally opening the pinchcock at *g* and blowing into the rubber tube X.

When upon cooling the apparatus, the gases which have collected disappear, the heating of the flask A is discontinued, the pinchcock between *a* and *b* is closed and A is disconnected and emptied. The water in C and B is now entirely free from absorbed gases and air can not enter from without, because the liquid in B is kept continually boiling. The apparatus is now ready for a determination, which is made as follows: The cooled flask A, whose capacity has been previously determined, is filled with the water to be examined and the stopper is pressed in so far that the air in the tube *a* is completely driven out. *a* is then connected with *b*, care being taken that in so doing no air bubbles are inclosed. The pinchcock between *a* and *b* is opened and the water in A is heated to gentle boiling. The dissolved gases are hereby driven over into the gas collector C. Steam is formed at the same time. The heating of the flask A must be so regulated that the gas and steam evolved never drive out more than half the liquid in C, otherwise there is danger of gas bubbles entering the tubes *d* and *e* and thus escaping.

After heating for about twenty minutes the flame under A is removed. In a few minutes the steam in A and C condenses, and water passes from B to C and A. If a gas bubble is observed in A which will not disappear when the neck of A is cooled



by applying a wet towel two or three times, the flask A must again be heated and cooled in the manner just described. The operation is ended when the hot liquid flows back and completely fills A.<sup>a</sup> The rubber tube *g* is then connected with a small piece of thermometer tube which is filled with water, and the gas standing over the hot liquid in C is driven over into a modified Winkler gas burette by blowing into the tube X and opening the pinchcock *g*.

The gases in the burette were allowed to cool for about ten minutes, and then passed into a simple absorption pipette filled with potassium-hydrate solution (one part KOH to two parts of water). The pipette was shaken two or three times to absorb the carbon dioxide, and the residual gases passed back into the burette. The burette was allowed

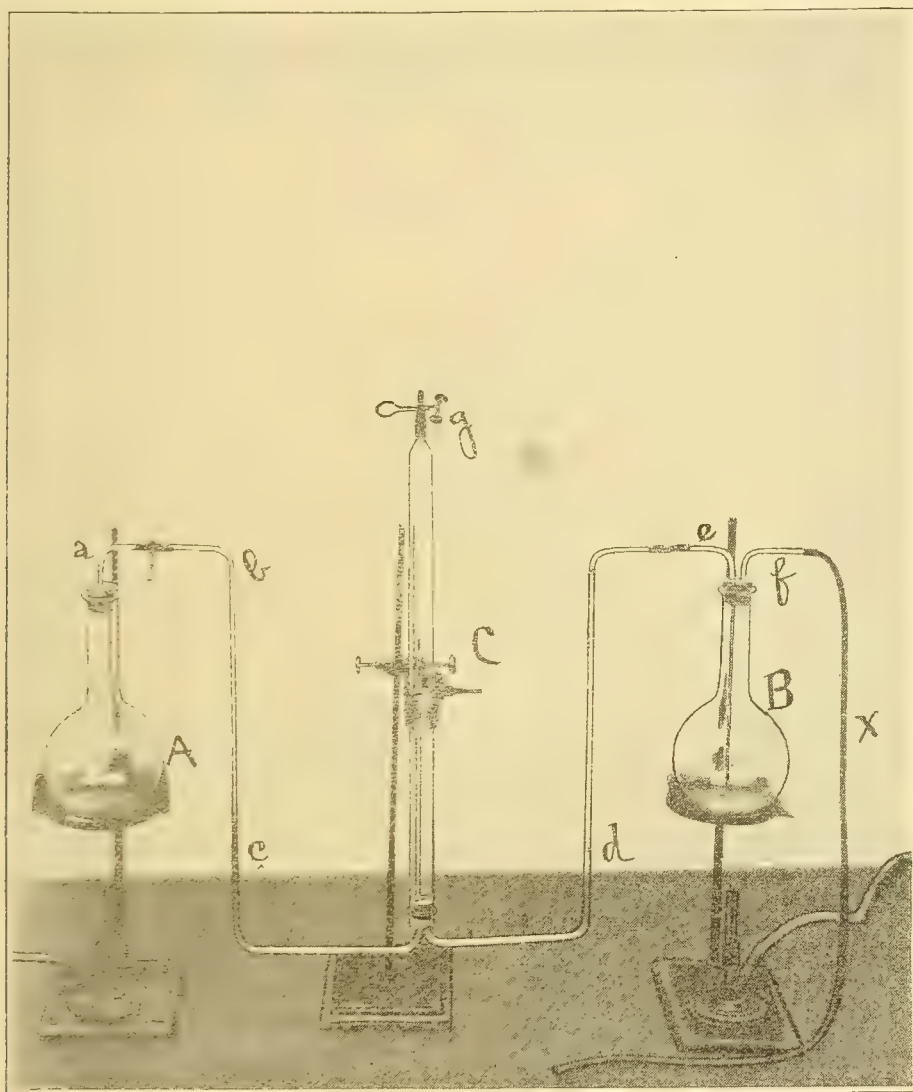


FIG. 1.

to stand for a few minutes and the volume of the gas read off. This gave the volume of oxygen+the volume of nitrogen. The gas was then passed into a double-absorption pipette filled with potassium pyrogallate, prepared by mixing 5 grams pyrogallic acid and 15 cc of water with 120 grams of potassium hydroxide and 80 cc of water.

<sup>a</sup> It has been observed in waters rich in bicarbonates that it is nearly impossible to drive off all the CO<sub>2</sub> by this means, but the O and N and part of the CO<sub>2</sub> are driven off in the course of a half-hour's boiling. Therefore the author did not continue boiling A, even though a small bubble of gas were present, more than one-half an hour.

After being shaken with this solution for about four minutes the gas was passed back into the burette, the burette allowed to stand for a few minutes, and the reading taken. The last reading gave the number of cc of nitrogen present, and the difference between the first and last reading, the number of cc of oxygen. A temperature and barometric pressure reading were also taken, to correct the gas volume to 0° C and 760 mm. pressure. Numerous precautions as to temperature, saturation of reagents, etc., not mentioned in the above brief sketch were taken, all of which can be found in any standard work on gas analysis.

CARBON DIOXIDE.—(In excess of that necessary to form normal carbonates.) The determination of the carbon dioxide existing in water in excess of that present as normal carbonates was made by a method given in Sutton's Volumetric Analysis and designed by Pettenkofer. One hundred cc of the water was treated in a flask with 3 cc of a saturated solution of calcium chloride, 2 cc of a saturated solution of ammonium chloride, and 45 cc of a saturated solution of calcium hydroxide, whose strength had previously been determined in terms of  $\frac{n}{10}$  hydrochloric acid, using lacmoid as indicator. The flask was stoppered, the solution well mixed, and the whole set aside for twelve hours to allow the calcium carbonate to settle. At the end of this time 50 cc of the clear solution was drawn off in a pipette and titrated with  $\frac{n}{10}$  hydrochloric acid, using lacmoid as indicator. This result was multiplied by three and subtracted from the amount of  $\frac{n}{10}$  hydrochloric acid necessary to neutralize 45 cc of the calcium hydroxide solution, thus giving the amount of calcium hydroxide solution that had been acted on by the carbon dioxide in terms of  $\frac{n}{10}$  acid. Multiplying the number of cc so found by 0.0022, the weight of carbon dioxide in 100 cc above that necessary to form normal carbonates was found. Dividing the weight so found by the weight of 1 cc of carbon dioxide at 0° C and 760 mm. pressure and multiplying the result by 10, the number of cc of carbon dioxide in a liter in excess of that necessary to form normal carbonates was given.

CARBON DIOXIDE.—(Given off from the bicarbonates when they are evaporated to dryness.) In making this determination the method of Cameron<sup>a</sup> for the "Estimation of carbonates and bicarbonates in aqueous solution" was used. By this method the amount of bicarbonic acid ion ( $\text{HCO}_3$ ) was determined, and from this we could easily estimate how much of the bicarbonic acid would remain as the normal carbonate and how much be given off as carbon dioxide. The method is as follows:

To one hundred cc of the water was first added a few drops of phenolphthalein. In case there were alkali carbonates present the usual red color would be evident. The solution was now titrated with a solution of  $\text{HKSO}_4$ , containing 6.758 grams to the liter, adding the  $\text{HKSO}_4$  solution at the rate of a drop every two or three seconds, until the red color had completely disappeared. The reading on the

<sup>a</sup>Report 64 U. S. Department of Agriculture; American Chemical Journal. 23,471 (1900).



burette was recorded, and to the clear solution was added one drop of methylorange. A pure yellow color resulted. The titration was continued with the  $\text{H}_2\text{SO}_4$  without refilling the burette until the change to a very slightly darker and reddish color was noted. The change was faint and required practice to detect. The reading at this point was also recorded.

The first reading recorded gives the amount of alkali carbonates present and must be multiplied by the factor 0.002979 for the result in grams of  $\text{CO}_3$  ions.

For the number of grams of  $\text{HCO}_3$  ions present the first recorded reading is multiplied by two and the result subtracted from the second reading, and this remainder is multiplied by the factor 0.003028. In no case were carbonates found in any of the springs by the above method, but only bicarbonates.

Having now obtained the weight of  $\text{HCO}_3$  ions in 1,000 cc of water, we next calculate the weight of  $\text{CO}_2$  given off when a like volume is evaporated to dryness, and dividing this result by the weight of one cc of carbon dioxide at  $0^\circ \text{C}$ . and 760 mm. pressure the number of cc of carbon dioxide given off from the bicarbonates is the result. Subtracting the number of cc of carbon dioxide given off from the bicarbonates from the number of cc of carbon dioxide in excess of that necessary to form normal carbonates, we have left the number of cc existing in solution in a free state.

**BICARBONIC ACID.**—The amount of this substance present in the spring was estimated during the process of determining the amount of carbon dioxide given off from bicarbonates in the paragraph above.

It will be noticed in several of the analyses of the different springs that the amount of carbon dioxide (set free from bicarbonates on evaporating to dryness) and calculated from the bicarbonic acid does not agree with the amount of bicarbonic acid found in solution. This is because the samples for determining the carbon dioxide and bicarbonic acid were taken at widely different periods, and the amount of bicarbonic acid had evidently changed somewhat during the intervening time. This is easily explained when we remember that many of the springs are supplied from two or three different spring heads, which doubtless vary from time to time both in their amount of flow and in the amount of bicarbonic acid held in solution.

For the determination of nitric and nitrous acid, free and albuminoid ammonia, and oxygen consuming capacity the methods as given in Mason's Examination of Water were followed in all their principal details. They are as follows:

**NITRIC ACID.**—In determining nitric acid, 100 c. c. of the spring water was treated with 2 drops of a saturated solution of sodium carbonate and evaporated to dryness on the water bath. The residue was treated with 2 c. c. of phenol sulphonic acid (made by mixing 148 c. c. of pure sulphuric acid, 12 c. c. of water, and 24 grams of phenol), a little water added, and then an excess of ammonia. The solution was transferred to a 100 c. c. Nessler jar, the volume made up to 100 c. c. with distilled water, and the depth of the yellow color compared with that produced by treating different measured amounts of standard potassium nitrate (containing 0.01 milligram of nitrogen as nitrate in each c. c.) in the same manner.

**NITROUS ACID.**—For this determination 100 c. c. of the water was placed in a 100 c. c. Nessler jar and treated with 1 drop of concen-

trated hydrochloric acid. One c. c. of sulphanilic acid (containing 1 gram in each 100 c. c. of water) was then added, followed by 1 c. c. of a solution of naphthylamine hydrochloride (obtained by boiling 0.5 grams of the salt with 100 c. c. of water for ten minutes at constant volume), and the whole well mixed. The Nessler jar was then set aside for half an hour, along with several other Nessler jars containing known amounts of a standard nitrite solution (containing 0.0001 milligram of nitrogen as nitrite in each c. c.), made up to 100 c. c. with nitrite-free water, and treated with hydrochloric acid, sulphanilic acid, and naphthylamine hydrochloride in the manner just described. By comparing the depth of pink color in the known and unknown solutions the amount of nitrite could be determined.

**FREE AMMONIA.**—A large flask of about 1½-liter capacity was connected to an upright bulbed condenser by means of a rather large glass tube and soft, new, rubber-stopper connections. In this was placed 5 c. c. of a saturated solution of sodium carbonate and 200 c. c. of ammonia-free water. The water was distilled off in 50 c. c. Nessler jars until no more ammonia was shown, when the jars were nesslerized. Five hundred c. c. of the water under examination was now added and the distillation in 50 c. c. Nessler jars continued till ammonia ceased to be given off. About four or five jars were usually necessary. These jars were nesslerized and the depth of color compared with that in other jars which contained known amounts of a standard ammonium chloride solution (containing 0.01 milligram of  $\text{NH}_3$  in each c. c.), made up to 50 c. c. with ammonia-free water and nesslerized in the same manner.

**TOTAL AMMONIA.**—The same apparatus was used as that mentioned in the paragraph above. In it were placed 200 c. c. of distilled water and 50 c. c. of alkaline permanganate solution (prepared by dissolving 200 grams of potassium hydroxide and 8 grams of potassium permanganate in 1,250 c. c. of water and boiling the whole down to about 1 liter). The water was distilled off in 50 c. c. Nessler jars till ammonia ceased to come over. Five hundred c. c. of water under examination was now added and the distillation continued till ammonia ceased to come off. Six jars were in all cases sufficient. These jars were nesslerized and compared with nesslerized jars of known strength just as in the determination of free ammonia. From the total ammonia thus found subtract the free ammonia and the result is the albuminoid ammonia in 500 c. c. of water.

Many precautionary details of the two above methods are not given, but can be found by consulting any good book on water analysis.

**OXYGEN-CONSUMING CAPACITY.**—In making this determination two solutions were first prepared: (1) A standard solution of potassium permanganate containing 0.3952 gram to the liter, each c. c. of which has 0.1 milligram of oxygen available for oxydation; and (2) a standard solution of oxalic acid containing 0.7875 gram of crystalized oxalic acid to the liter. The value of the oxalic acid in terms of the permanganate was determined by boiling 10 c. c. of oxalic-acid solution and 200 c. c. of distilled water with 10 c. c. of sulphuric acid (1–3) and titrating the fluid while boiling with the standard permanganate solution to the appearance of a pink color. In the actual determination 200 c. c. of the water in a porcelain dish was treated with 10 c. c. of sulphuric acid (1–3) and the whole brought to the boiling point. Standard permanganate was run in until the water was quite red and the boiling continued for ten minutes, adding permanganate every now and then to keep the pink color about the same. The boiling was now stopped,



10 c. c. of oxalic acid run in, which destroyed the color, and the solution titrated with the standard permanganate to the appearance of a pink color. From the total number of c. c. of permanganate used was subtracted the number of c. c. equal to 10 c. c. of oxalic acid. The result gives the number of c. c. of permanganate required for 200 c. c. of water.

**TOTAL SOLIDS.**—Measured amounts of the water were evaporated to dryness in weighed platinum dishes on the steam bath. The dishes were dried for twelve hours at the temperature of boiling water, cooled in the desiccator, and weighed. The increase in weight of the dish gives the amount of solids present in the volume of water used.

To determine chlorine, iron and aluminum, manganese, bromine, iodine, arsenic, and boric acid large quantities of the water were evaporated to dryness after the addition of a small amount of sodium carbonate. The residue thus obtained was boiled with distilled water, transferred to a filter and thoroughly washed with hot water. The residue in the paper was dried and transferred to the dish in which the evaporation was made, the paper burned and added, and the whole kept for the determination of iron, aluminum, and manganese. The filtrate was made to a definite volume and aliquot portions taken to determine the constituents mentioned above other than iron, aluminum, and manganese.

**CHLORINE.**—An aliquot portion from the above filtrate was treated with a few drops of phenolphthalein and  $\frac{n}{10}$  HKSO<sub>4</sub> added at the rate of a drop every few seconds until the red color had entirely disappeared, thus showing that all of the carbonates had changed to bicarbonates.<sup>a</sup> A few drops of potassium chromate indicator were then added and the chlorides titrated with a solution of silver nitrate each c. c. of which would precipitate 1 milligram of chlorine.

**IODINE AND BROMINE.**—The qualitative tests for the presence of iodine and bromine were very much the same as those used in Fresenius. Another aliquot portion from the above filtrate was evaporated to dryness on the steam bath. Two or 3 c. c. of water were added to dissolve and soften up the residue and enough absolute alcohol added to bring the percentage of alcohol down to about 90 per cent. This was boiled and filtered and the treatment with 90 per cent alcohol repeated once or twice. Two or 3 drops of sodium hydrate solution were added to the filtrate and it was evaporated to dryness. The same process of extracting with 90 per cent alcohol was repeated on the new residue and the extract filtered off from the undissolved portion. A drop of sodium hydrate was added to the filtrate and it was evaporated to dryness. The residue was treated with a little distilled water, dilute sulphuric acid added to acid reaction, the liquid transferred to a test tube, and a little carbon disulphide added. Three or 4 drops of potassium nitrite solution were then added and the test tube shaken. The presence of iodine was shown by a pink color in the carbon bisulphide. Chlorine water was then added until the pink color due to the iodine had disappeared, then a little more chlorine water.

The presence of bromine was shown by an orange color in the carbon bisulphide.

In no case did a sample of spring water give nearly as distinct a reac-

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<sup>a</sup>See Cameron's paper in Amer. Chem. Journal, 23, 481, 1900.

tion for iodine and bromine as did a known sample of water containing 0.2 milligram of both iodine and bromine, as iodides and bromides, to the liter.

An attempt was made to determine iodine and bromine quantitatively in spring No. 15 by evaporating down a large volume of water, but the attempt failed because both these elements were present in such minute traces. The method used was the same as that described by Gooch and Whitfield<sup>a</sup> and is as follows: The iodides and bromides were extracted with 90 per cent alcohol in the same manner as described above.

The alcohol extract was evaporated to dryness, acidulated with dilute sulphuric acid, mixed with a ferric sulphate solution, and distilled from a retort which was joined to a condenser sealed by a U-tube filled with water and carbon bisulphide. If a very small amount of iodine had been present it would have colored the carbon bisulphide and could have been titrated with sodium thiosulphate, but not enough was present.

After the distillation had been continued long enough to be sure that all iodine had been volatilized, crystals of potassium permanganate were added and the distillation continued the same as before, except that the U-tube acting as a seal was now filled with water and chloroform. The contents of the tube were treated with sodium hydroxide and zinc in a breaker and the chloride and bromide solution so formed acidified with nitric acid and precipitated with silver nitrate. The precipitate was dried and weighed. It was then dissolved in potassium cyanide and the silver precipitated by electrolysis.<sup>b</sup> In this way data on the weight of the combined silver chloride and bromide and the weight of the silver in same was determined. From this the weight of the bromine could be calculated, which in this case was nothing.

**ARSENIC ACID.**—An aliquot portion of the above filtrate was acidified with hydrochloric acid, the solution heated to 70° C., and a current of hydrogen sulphide passed through for several hours. In case either arsenic, copper, or lead were present they would be precipitated. No precipitation took place in any of the springs.

**BORIC ACID.** A test for boric acid was made in the following manner: A part of the above filtrate was evaporated to dryness, treated with a cubic centimeter or two of water and slightly acidified with hydrochloric acid. About 25 or 30 c. c. of absolute alcohol was added, the solution boiled and filtered. This was repeated. The filtrate was made slightly alkaline with sodium hydrate and evaporated to dryness. A very little water was added, the solution slightly acidified with hydrochloric acid, and a strip of tumeric paper placed in the liquid. The whole was evaporated to dryness on the steam bath, and the heating continued until the tumeric paper had become entirely dry. In case boric acid were present the tumeric paper took on a cherry-red color.

A quantitative determination of boric acid was made in the case of two springs to serve as an example of all the other springs.

The method used was the same as that described by Gooch,<sup>c</sup> except that a slightly different form of apparatus was used.

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<sup>a</sup> Bulletin 47 of U. S. Geological Survey.

<sup>b</sup> American Chemical Journal, vol. 8, p. 421.

<sup>c</sup> American Chemical Journal, vol. 9, p. 23.



The apparatus used by the author (Fig. II) consisted of a round-bottomed flask with a constricted neck joined to an upright bulbed condenser by means of a glass tube slightly sloping toward the flask instead of being bent at right angles. The flask was heated by being immersed in a paraffin bath, and the distillate was received in a small flask joined to the condenser by means of a grooved cork. The method was as follows:

An aliquot portion of the above filtrate evaporated to dryness, was slightly acidified with acetic acid and transferred to the round-bottomed

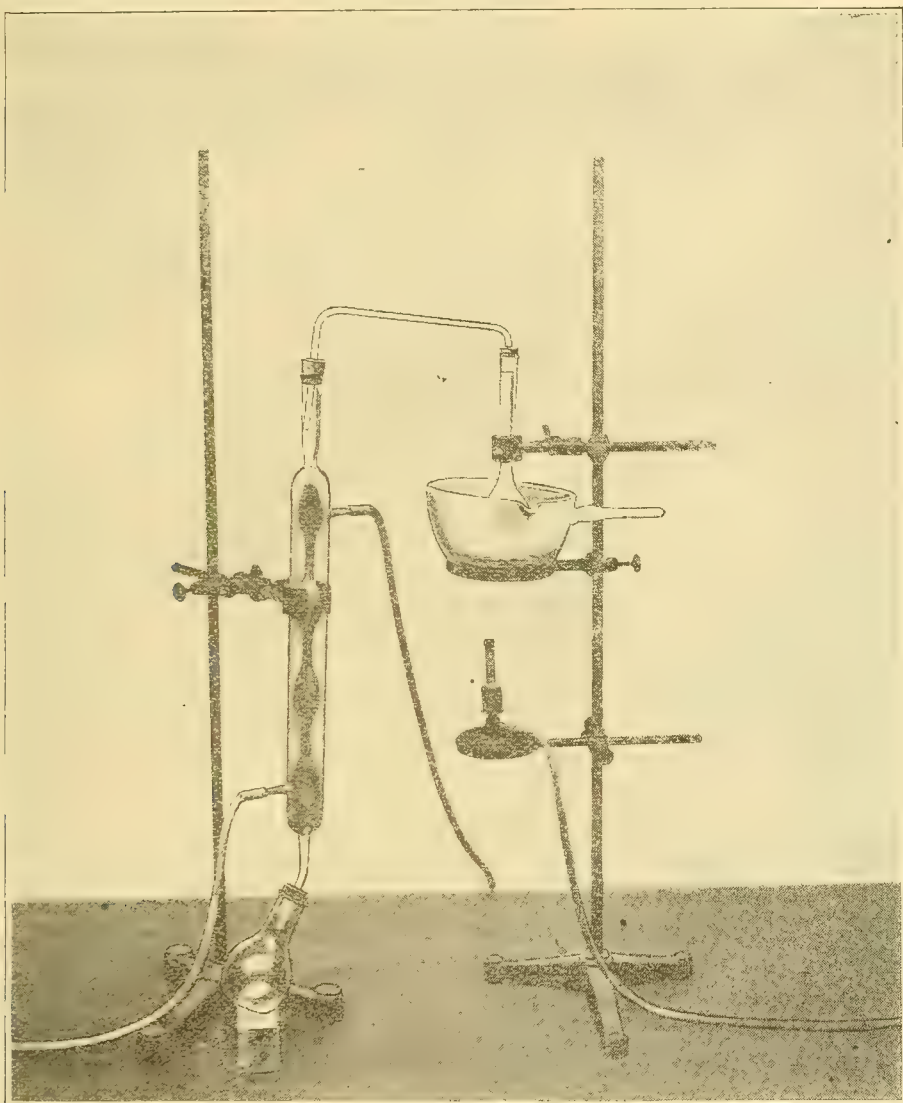


FIG. 2.

flask, 10 c. c. of methyl alcohol was added, the flask lowered in the paraffin bath, and distilled to dryness at a temperature of  $130^{\circ}\text{C.}$  to  $140^{\circ}\text{C.}$ , collecting the distillate in the flask attached to the condenser with a grooved stopper. The paraffin bath was lowered, the flask allowed to cool, and 10 c. c. more of methyl alcohol added. This was then distilled over and the same process repeated six times, except that after the fourth time a couple of drops of acetic acid were added. A large platinum crucible now received about 1 gram of quicklime and was blasted until it ceased to lose weight. The constant weight was recorded and the distillate transferred to the crucible. The alcoholic solution of

boric acid and the quicklime were stirred together for about fifteen minutes with a platinum rod to be sure that all boric acid was fixed.

The volatile contents of the crucible were now evaporated off at a low temperature. It was found necessary to grease the edges of the crucible with vaseline to keep the solution from crawling over. After the contents of the crucible had been evaporated to dryness the crucible was fully dried in the air bath and finally blasted. The increase in weight of the crucible gives the weight of boric anhydride ( $B_2O_3$ ) present.

IRON, ALUMINUM, AND MANGANESE.—The residue spoken of previously that was reserved for the determination of iron, aluminum, and manganese was treated with hydrochloric acid and evaporated to dryness. It was thoroughly dried at about  $120^\circ C.$ , again taken up with water and hydrochloric acid and filtered. The filtrate was evaporated to dryness and dried at  $120^\circ C.$  It was then taken up with hydrochloric acid and water and filtered again. This filtrate was heated to the boiling temperature, and ammonia added, a drop at a time, until it could be very faintly smelled coming off from the solution. The solution was then filtered and the precipitate well washed with hot water, burned and weighed as  $Fe_2O_3$  and  $Al_2O_3$  in the ordinary manner.

The ammoniacal filtrate from above was treated with a few drops of bromine, more ammonia was then added, and the whole boiled after stirring up. The vessel was removed from the source of heat, cooled a little, and a little more bromine and ammonia added. This process repeated once or twice precipitated all the manganese as the oxide. The solution was made slightly acid with acetic acid, filtered and washed at once with hot water. The filter and contents were burned and weighed as  $Mn_3O_4$ . This is the method by which the iron, aluminum, and manganese were determined in springs 24 to 46, inclusive. In the first 23 springs these three elements were determined in the same portion that was used for the estimation of calcium and magnesium.

SILICA.—In this determination a large quantity of water was evaporated to dryness in platinum with the occasional addition of small amounts of hydrochloric acid. After all the water had been evaporated to dryness, the dish and contents were completely dried at  $120^\circ C.$  The residue was taken up with hydrochloric acid and water, heated and filtered, washing the residue thoroughly with hot water. This process took out most of the silica. The filtrate was then evaporated to dryness, dried thoroughly at  $120^\circ C.$ , again taken up in hydrochloric acid solution by heat, and filtered. The filtrate was made to a definite volume, aliquot portions of which were used for the determinations of calcium, magnesium, sulphuric acid, potassium, sodium, lithium, and phosphoric acid. The two residues were transferred to a crucible, burned and blasted in the ordinary way, and finally weighed as silica.

CALCIUM AND MAGNESIUM.—An aliquot portion of the above filtrate was first treated with ammonia and filtered, then treated with ammonia and bromine water and filtered, and finally treated with ammonium oxalate in the usual manner. This was allowed to stand over night, the liquid filtered off, and the precipitate dissolved in hydrochloric acid and reprecipitated with ammonia and a little extra ammonium oxalate. This was allowed to stand over night and filtered and washed on the same paper previously used. The precipitate was dried, trans-



ferred to a crucible, burned and blasted in the ordinary way, and finally weighed as calcium oxide. The combined filtrates were evaporated to dryness in platinum and the major part of the ammonium salts driven off by the aid of heat. The residue was dissolved in dilute hydrochloric acid and filtered. The filtrate was made slightly ammoniacal, enough sodium phosphate solution added, a drop at a time, to precipitate all magnesium, and 10 cc. of concentrated ammonia finally added, drop by drop. The beaker was covered and allowed to stand over night, filtered, washed with dilute ammonia water, dried, blasted, and weighed as magnesium pyrophosphate.

SULPHURIC ACID, POTASSIUM, SODIUM, AND LITHIUM.—Another portion of the above filtrate was precipitated while boiling with hot, dilute barium chloride, and after standing filtered from the precipitated barium sulphate, which was washed, dried, burned, and finally weighed in the ordinary way.

The filtrate was evaporated to dryness and taken up with water. This solution was precipitated with a solution of barium hydrate and filtered off from the insoluble magnesium hydrate. The magnesium hydrate precipitate was well washed and the combined filtrate and washings treated with ammonia, ammonium carbonate, and a little ammonium oxalate to precipitate barium and calcium. This precipitate was allowed to stand over night, filtered off and well washed. The filtrate and washings were evaporated to dryness on the steam bath, dried, and all of the ammonium salts driven off by gentle heat. The residue was taken up with water, filtered through a small filter, using as little wash water as possible, evaporated to a small volume, and finally again precipitated with a drop of ammonia and two to three drops of ammonium carbonate and oxalate. If any precipitate appeared, which was not usually the case, it was filtered off and the same process repeated. In any case, the solution was filtered from the magnesium hydrate that had precipitated out on concentrating the solution. The filtrate was then evaporated to dryness and all ammonium salts driven off by heating in platinum to a little below redness. The residue was taken up with a little water and filtered through a small filter, again using as little wash water as possible, and again heated in platinum to a point slightly below red heat. By this time all of the magnesia should have been removed. The residue was then taken up with a little water, filtered into a weighed platinum dish, treated with a few drops of hydrochloric acid, and evaporated to dryness. This residue was thoroughly dried, heated to a little below redness, cooled in a desiccator, and finally weighed as the combined chlorides of potassium, sodium, and lithium.

The determination of lithium was then made according to the method of Gooch<sup>a</sup>—i. e., the combined chlorides were dissolved in water and transferred to a small beaker, where they were again evaporated nearly to dryness. About 30 cc. of amyl alcohol was added and the contents of the beaker boiled until the temperature had risen to approximately the boiling point of the amyl alcohol, showing that all of the water had been driven off. The liquid was cooled slightly, and a drop of hydrochloric acid was added to reconvert small amounts of lithium hydrate to lithium chloride. The boiling was then continued to again drive off all water, until finally the liquid had reached a volume of about 15 cc.

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<sup>a</sup>American Chemical Journal, vol. 9, p. 33.

The amyl alcohol was then filtered off in a weighed platinum dish and the filter washed with a little amyl alcohol that was also allowed to run into the dish. The amyl alcohol was driven off from the filter and beaker in the air bath and these two kept for the determinations of potassium and sodium. The contents of the platinum dish were evaporated to dryness, treated with a little dilute sulphuric acid, and finally burned and weighed. This gave the weight of the lithium sulphate, from which was subtracted 0.0017 gram to correct for the solubility of the sodium and potassium chlorides in the amyl alcohol. The residue was finally tested with the spectroscope for the lithium line. In every case the lithium line was found, but in no case was any lithium sulphate left after applying the correction of 0.0017 gram. The lithium was therefore reported as traces.

The contents of the beaker and filter from which the amyl alcohol had been driven were then used for the determination of potassium and sodium. The contents of the beaker were dissolved in hot water and passed through the filter, which was thoroughly washed. The combined filtrate and washings were transferred to a porcelain dish, treated with platinum chloride solution, and evaporated nearly to dryness. The residue was treated with 80 per cent alcohol and thoroughly washed on the filter with this medium until all platinum chloride had been washed out. The filter paper was dried at the temperature of boiling water, and the residue dissolved in water and passed into a weighed platinum dish from which the water was evaporated off, the dish and contents dried at the temperature of boiling water, and finally weighed as potassium platinic chloride. An addition of 0.0008 gram of potassium chloride to the weight of this substance found is necessary.

The weight of the sodium chloride is found by subtracting the combined weights of the lithium chloride (in this case nothing) and the potassium chloride (corrected) from the total weight of the three chlorides.

Of course, if the amyl alcohol in the determination of lithium above is not evaporated to exactly 15 cc., the corrections will be different from those mentioned above.<sup>a</sup>

PHOSPHORIC ACID. —A third aliquot portion from the filtrate mentioned above was treated with about 10 cc. (con.) nitric acid and evaporated in a porcelain dish nearly to dryness to drive off hydrochloric acid. The residue was taken up with water and if necessary filtered. Ammonia was added to alkalinity and then nitric acid to just bring back to acidity. Some ammonium nitrate was added and the beaker heated in the water bath to 45° to 50° C. Molybdate solution was then added and the solution kept at a temperature of 45° to 50° C. for half an hour. The yellow precipitate formed at this point appeared in most cases only in traces, but in a few cases it was filtered off and washed with cold water till it was entirely free of nitric and molybdic acids. The precipitate and filter were then transferred to a beaker, a little water added, and the paper and contents thoroughly beaten into a pulp. The yellow precipitate was then dissolved by the addition of a small amount of standard potassium hydroxide solution (1 c. c. = 1 milligram of  $P_2O_5$ ); phenolphthalein was added and the solution titrated with standard nitric acid solution of exactly the same strength as the alkaline solution. From the data so obtained the

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<sup>a</sup>For the discussion of this, see the original article already mentioned.



amount of phosphoric acid ion in the water can be calculated.<sup>a</sup> For the determination of fluorine the same method was used as described by Gooch and Whitfield.<sup>b</sup> For the determination of barium and strontium a combination of Gooch and Whitfield's method along with another was employed. They are briefly as follows:

**FLUORINE.**—A large quantity of water was evaporated to dryness and filtered off from the residue which was washed on the filter. The filter and contents were dried, the contents placed aside and the filter burned and the ash added to the contents. The whole was now transferred to a flask, which was so arranged as to allow a current of air to pass through any liquid that might be in the bottom, and from there into an attached U-tube, partly filled with dilute ammonia. Concentrated sulphuric acid was added to the contents of the flask, and a current of dry air passed through the liquid, and from there into the U-tube. The flask was heated to 150° C. If any considerable amount of fluorine had been present it should have been volatilized as silican tetra fluoride and then decomposed by the dilute ammonia in the U-tube, depositing silica in so doing. No silica appeared at this point in the spring examined. The contents of the U-tube was removed and treated with zinc oxide dissolved in ammonia, evaporated till ammonia ceased to come off and filtered. The filtrate was treated with calcium chloride, followed by sodium carbonate in boiling solution, filtered and washed. The residue was ignited and extracted with acetic acid. Operating in this way no residue of calcium fluoride was found.

**BARIUM AND STRONTIUM.**—The residue left in the flask from the above determination was transferred to platinum, treated with enough hydrofluoric acid to volatilize all silica and with some sulphuric acid and evaporated to dryness. This treatment was repeated. The residue was fused with sodium carbonate, treated with water and a few drops of alcohol, filtered, and washed. The contents of the filter was digested with hot dilute acetic acid to dissolve barium, strontium, magnesium, and calcium carbonates and filtered. The filtrate was then nearly neutralized with ammonia and about fifty times the weight of the combined sulphates in ammonium sulphate was added, which ammonium sulphate was dissolved in four times its weight of water. The whole was allowed to stand over night. In case barium or strontium were present they would be precipitated here as the sulphates. Only a slight nonweighable opalescence appeared, however, in the spring examined. For the sake of completeness, and to be able to test the final residue with the spectroscope, the process was carried on just as in an actual determination. The precipitated sulphates were filtered and washed with a concentrated solution of ammonium sulphate, till no more calcium was present in the wash water, as shown by the ammonium oxalate test. The filter was ignited and the residue evaporated to dryness with a drop or two of sulphuric acid. The combined sulphates so obtained from a very large quantity of water did not weigh over 0.5 milligram, and most of this was calcium sulphate. The extremely small residue was fused with sodium carbonate, treated with a very small quantity of water, and filtered on a very small filter paper, washing only once. Dilute hydrochloric acid was now passed through

<sup>a</sup> Bul. 46 (revised edition), U. S. Department of Agriculture, Division of Chemistry. 1899.

<sup>b</sup> Bul. 47, U. S. Geological Survey.

the filter and the filtrate containing any barium and strontium as the chlorides was collected in a platinum dish and evaporated to dryness. The minute residue was tested by the spectroscope for the barium and strontium lines, both of which were faintly seen.

**STRONTIUM.**—This substance was determined in a separate portion. The oxide of calcium, which had been obtained by blasting the ammonium oxalate precipitate in the determination of calcium, was transferred to a small flask and dissolved in concentrated nitric acid. The acid was entirely evaporated off by means of a current of air and heating in a paraffin bath to  $135^{\circ}$  C. The flask and contents were dried at  $140^{\circ}$  C., and the completely dried nitrates were treated with the least possible quantity of a mixture of equal parts of absolute alcohol and ether, necessary to dissolve the calcium nitrate. The flask was corked, allowed to stand over night, and the insoluble residue, if any, filtered off on the smallest possible filter and washed with the ether-alcohol mixture. The strontium nitrate on the filter was washed with water into a platinum dish and evaporated to dryness. The dish was blasted to change the nitrate to the oxide. No increase in the weight of the dish was noticed, yet upon treating the contents of the dish with a little hydrochloric acid, evaporating nearly to dryness and testing with the spectroscope, the strontium lines were seen.

#### THE MEDICINAL VALUE OF THE VARIOUS SALTS AND GASES USUALLY PRESENT IN MINERAL WATERS.

**CARBONATES AND BICARBONATES.**—One of the most important groups of mineral waters are the alkaline waters, which are characterized by the presence, in predominating quantities, of one or more of the alkaline or alkaline earth carbonates or bicarbonates. These are the carbonates or bicarbonates of sodium, potassium, lithium, calcium, and magnesium. In case iron is present in large quantities as the bicarbonate we have a water belonging to the chalybeate class. Since these waters are alkaline they are excellent remedies in cases of sour stomach and in sick headaches which arise from acid dyspepsia. They act very markedly on the mucous membranes, increasing the flow of the gastric juice and other digestive fluids and are consequently of use in many cases of indigestion. In conjunction with the sulphated salines they give excellent results when used in the treatment of catarrhal conditions of the stomach and intestines. Such waters correct acidity of the urine, markedly increase the flow of urine and help to dissolve uric acid deposits. They are therefore of value in cases of rheumatism, gout, diabetes, etc.

*Sodium carbonate and bicarbonate.*—Sodium carbonate or bicarbonate appears as a normal constituent of the blood, lymph, and nearly all secretions of the mucous membrane. Where conditions arise that cause these fluids to become acid, waters containing carbonate or bicarbonate of soda are of value in counteracting the effect. Waters containing either of these substances have been used with excellent effect in the treatment of acid dyspepsia, diabetes, where sugar has been caused to disappear from the urine by their use, and in breaking up and eliminating deposits of uric acid and uric acid sand and gravel.

*Potassium carbonate and bicarbonate.*—Both of these salts are readily soluble in water. The bicarbonate is the one usually present in mineral waters. The properties of this salt are very much the same



as those of sodium bicarbonate. It increases the flow of urine and corrects acidity of the bodily fluids. Its chief use is in the treatment of stone in the bladder.

*Lithium carbonate and bicarbonate.*—Lithium carbonate is very sparingly soluble in water, while the bicarbonate is quite soluble. It is in the latter form that lithium is most often reported in mineral waters. This compound is most frequently used in cases of rheumatism and gout, where it forms a very soluble urate which is easily eliminated from the system. In cases of gravel and calculi it is a very valuable disintegrating agent.

*Magnesium carbonate and bicarbonate.*—These two substances are mild laxatives and are perhaps the best of all the carbonates and bicarbonates in correcting an acid condition of the stomach and curing sick headache caused by constipation. They are valuable agents in breaking up deposits in the bladder.

*Calcium carbonate and bicarbonate.*—Calcium is usually present in waters as the bicarbonate. Both of these compounds are quite different in their effects from the other carbonates and bicarbonates mentioned. While the others are evacuant and promote secretions, the calcium compounds constipate and decrease the secretions. Very obstinate cases of chronic diarrhea have often been cured by a sojourn at a spring rich in calcium bicarbonate. Uric acid gravel and calculi are disintegrated and eliminated by the free use of calcic carbonated waters.

*Ferrous and manganous bicarbonates.*—Neither iron nor manganese ever occur in mineral waters as the carbonate, but usually as the bicarbonate. Both of these compounds have practically the same effect. When taken internally, they are dissolved by the gastric juice and taken into the blood. They increase the appetite and the number of red blood corpuscles. It will thus be seen that such waters give excellent results when used as a tonic or in cases of anæmia. Too long continued use of waters rich in bicarbonate of iron or manganese result in constipation and derangement of the digestion.

**CHLORIDES.**—Chlorine occurs in waters as chlorides, in combination, most frequently, with sodium, potassium, or lithium, and sometimes with calcium, magnesium, or iron. The chlorides form the basis of that large group of mineral waters, the muriated salines.

*Sodium chloride* occurs in almost all mineral springs to some slight extent, but in the muriated saline waters it occurs in large quantities as a predominating constituent. Waters containing large quantities of this substance are chiefly used in giving baths, which increase the action of the skin, and by absorption through the pores serve as a genuine tonic. Taken internally the flow of the digestive fluids is promoted and the appetite increased. Putrefactive changes in the intestines are also prevented. In large doses sodium chloride increases the flow of urine and the amount of urea present in the same.

*Potassium chloride* has very much the same effect on the human system as does sodium chloride.

*Lithium chloride* has practically the same effect as lithium carbonate and bicarbonate mentioned above.

*Magnesium chloride* is often used medicinally as a cathartic and to increase the flow of bile.

*Calcium chloride* occurs in a number of muriated saline springs. It is used in cases of general debility as a tonic. It increases the flow of

urine and perspiration and waters containing it are used in the treatment of scrofulous diseases and eczema.

*Ferrous chloride*.—The occurrence of this substance in mineral waters is rather rare. When present, however, it acts as a tonic and in general has the same properties as ferrous bicarbonate, already mentioned.

*Ammonium chloride*.—When used internally it has the stimulating effect of ammonia. It is used in nervous cases as ovaralgia, sciatica, and other neuralgic disorders. In congestion of the liver its use has been beneficial. Externally it is used as a wash for ulcers and sores. It, however, seldom occurs in springs in quantities large enough to be of any value.

SULPHATES are frequently found in mineral waters, and when present in large quantities give rise to that large class, the sulphated salines.

*Sodium and magnesium sulphates*, or Glauber and Epsom salts respectively, in small doses act as a laxative, in large doses as a cathartic. They are both valuable in increasing the flow of the intestinal fluids and in increasing the flow of urine, accompanied by an increased elimination of urea. Waters containing these salts are of great service in eliminating syphilitic, scrofulous, and malarial poisons from the system, and in eliminating mercury and other metallic poisons. Persons suffering from obesity, derangement of the liver, and Bright's disease are perhaps the most benefited by this class of waters. It must be borne in mind that such waters should be used with great care by the feeble and anaemic.

*Potassium sulphate* is frequently present in mineral waters, but in smaller quantities than the magnesium and sodium salts. Its action is practically the same as that of the other two sulphates mentioned above.

*Calcium sulphate* occurs in a great many mineral waters, and is the component that gives to them the property of permanent hardness. It is not used medicinally.

*Iron and aluminum sulphates* are usually found associated with each other in mineral waters. They are both powerful astringents. The waters containing iron sulphate are also used as tonics, but this is not nearly as good a form in which to give the iron as is the bicarbonate. Because of their astringent action, waters containing these two substances have been used with success in treating locally inflamed parts of the mucous membranes and ulcers on the outside of the body.

IODIDES.—The iodides are usually reported in mineral waters as the potassium or sodium salt. They occur in nearly all cases only as traces, yet their action is shown in a marked degree. They are alterative in effect and are consequently used in the treatment of scrofula, rheumatism, and syphilis. While drinking waters containing iodides the flow of urine is very much increased and mercurial and other metallic poisons are rapidly eliminated from the system.

BROMIDES act as alteratives in much the same way as iodides but to not so marked an extent. They also act as sedatives.

PHOSPHATES in mineral waters are usually reported in one of three forms, viz, sodium, iron, or calcium phosphate. The sodium phosphate acts as a mild laxative, the iron phosphate as a tonic, and the calcium phosphate as a medicine in those conditions of the body where lime salts are deficient, as rickets, etc.

BORATES.—Boric acid is not a very common constituent of natural waters, but is found as the sodium salt in springs of southern Cali-



fornia in large amounts. Borax has been used internally to dissolve lithic acid gravel. It promotes the menstrual flow, so may be used in catamenial irregularities. Applied as a douche in catarrhal conditions of the uterus it is of value.

**NITRATES.**—Any nitric acid that may appear in a water is usually reported as sodium nitrate. This compound does not usually occur in waters to a marked extent unless they are contaminated. When present in large enough amounts it increases the flow of urine and acts as a purgative.

**SILICA.**—Silica appears in mineral waters both as free silica and as silicates. The medicinal value of silica has not been thoroughly investigated, although one or two investigations have been made which seem to show that it is of value when taken for cancer, and that sugar and albumin have disappeared from the urine upon using it.

The gases that usually occur in water are nitrogen, oxygen, carbon dioxide, and hydrogen sulphide.

**NITROGEN AND OXYGEN** are present in all waters that have come in contact with the air. On account of the limited solubility of both they can not occur in waters in very large quantities. Neither of them when present in waters has any medicinal value.

**CARBON DIOXIDE** is present in all natural waters to some extent, but in some springs the amount is very large, thus giving rise to that large class of carbonated waters of which the Saratoga springs furnish a good example. Such waters are extremely palatable, and large quantities can be drunk without the full feeling which so often follows copious drinking of water. In moderate quantities such waters increase the flow of the saliva, promote digestion, and tend to increase the flow of urine. Obstinate cases of nausea can be often relieved by the use of small quantities of highly carbonated waters.

**HYDROGEN SULPHIDE** is present in many natural waters, giving to them the odor of decayed eggs, and forming that large class, the sulphuretted waters. When such waters are taken internally they act as an alterative, and are consequently of value in the treatment of syphilitic diseases. They increase the activity of the intestines, kidneys, and sweat glands, so are of use in the treatment of rheumatism and gout. Excellent results have been obtained when these waters were used in treating many skin diseases and malaria.

#### THE MEDICAL VALUE OF THERMAL WATERS.

The curative effects of thermal waters are undoubtedly due, to a large extent, to their stimulating effects on the excretory organs of the skin and the kidneys. To fully understand this we have only to examine the routine through which a patient passes at these thermal resorts. The pores are first thoroughly opened and sweating begun by immersing the patient in hot water for from three to ten minutes. The patient is then placed in the steaming room for about five minutes and at the same time drinks copiously of hot water. This treatment, of course, produces a profuse perspiration. After this the patient is wrapped in blankets and passed on to a warm room for twenty to thirty minutes, where the perspiration runs off in streams. After this the patient is rubbed down and allowed to dress. A desire to urinate soon comes. Thus we see that the system is thoroughly flooded with water and washed out each day, and that tissue changes take place with won-

derful rapidity. It is no wonder then that uric acid, syphilitic poisons, other materials of disease, and mercurial and other metallic poisons are soon eliminated from the system. With such effects as those mentioned above, hot baths then must be of value in the treatment of rheumatism, gout, syphilis, neuralgia, etc.

#### ACKNOWLEDGMENTS.

In writing the above pages on the medicinal value of mineral waters I wish to acknowledge my indebtedness to the following works:

“Mineral Springs of the United States and Canada,” by G. E. Walton; “Mineral Waters of the United States and Their Therapeutic Uses,” by J. K. Crook, and “Mineral Waters of Missouri, a Report of the Missouri Geological Survey,” by Paul Schweitzer.

In the following pages there first appears a table showing the temperatures of the springs at different dates. This is followed by a second table showing the flow, in gallons per twenty-four hours, of each spring. Finally the analysis of each spring is given, accompanied by a hypothetical combination of the various bases and acids, and any remarks that might be of interest.

#### *Temperature of springs.*

No.	Name.	Date.	Degrees centigrade.	Degrees Fahrenheit.
1	Egg spring .....	(Nov. 7, 1900	61.9	143.4
		(Jan. 8, 1901	61.7	143.1
2	Arsenic spring .....	(Nov. 8, 1900	51.9	125.4
		(Jan. 8, 1901	53.9	129.0
3	Arlington spring .....	(Nov. 9, 1900	61.7	143.1
		(Jan. 8, 1901	61.3	142.3
4	Cliff spring .....	(Nov. 10, 1900	55.9	132.6
		(Jan. 8, 1901	52.4	126.3
5	Avenue spring .....	(Nov. 12, 1900	61.4	142.5
		(Jan. 8, 1901	61.9	143.4
6	Boiler House spring .....	(Nov. 13, 1900	57.5	135.5
		(Jan. 8, 1901	58.3	136.9
7	Imperial spring (north) .....	(Nov. 14, 1900	60.1	140.2
		(Jan. 8, 1901	60.8	141.4
8	Crystal spring .....	(Nov. 16, 1900	35.2	95.4
		(Jan. 8, 1901	36.2	97.2
9	Rector spring .....	(Nov. 17, 1900	61.1	142.0
		(Jan. 8, 1901	62.4	144.3
10	Cave spring .....	(Nov. 19, 1900	57.4	135.3
		(Jan. 8, 1901	57.2	135.0
11	Little Iron spring (north) .....	Jan. 8, 1901	56.8	134.2
12	Little Geyser spring .....	(Nov. 22, 1900	36.2	97.2
		(Jan. 8, 1901	36.2	97.2
13	Little Iron spring (south) .....	Jan. 8, 1901	56.3	133.3
14	Ral spring .....	(Nov. 23, 1900	60.9	141.6
		(Jan. 8, 1901	62.8	145.0
15	Big Iron spring .....	(Nov. 24, 1900	63.9	147.0
		(Jan. 7, 1901	63.9	147.0
16	Imperial spring (south) .....	(Nov. 26, 1900	60.8	141.4
		(Jan. 8, 1901	60.9	141.6
17	Arsenic spring (north) .....	(Nov. 28, 1900	55.4	131.7
		(Jan. 8, 1901	56.4	133.5
18	Hitchcock spring .....	(Nov. 27, 1900	57.3	135.2
		(Jan. 8, 1901	57.3	135.2
19	Sumpter spring .....	(Dec. 1, 1900	56.4	133.5
		(Jan. 8, 1901	56.1	133.0
20	Superior spring (north) .....	(Dec. 3, 1900	46.3	115.3
		(Jan. 8, 1901	44.5	112.1
21	Alum spring .....	(Dec. 4, 1900	43.3	109.9
		(Jan. 8, 1901	46.0	114.8
22	Superior spring (south) .....	(Dec. 5, 1900	57.1	134.8
		(Jan. 8, 1901	56.5	133.7
23	Twin spring (north) .....	(Dec. 6, 1900	62.0	143.6
		(Jan. 8, 1901	62.4	144.3
24	Twin spring (south) .....	(Dec. 7, 1900	62.3	144.1
		(Jan. 8, 1901	60.3	140.5



*Temperature of springs—Continued.*

No.	Name.	Date.	Degrees canti- grade.	Degrees Fahren- heit.
25	Old Hale spring .....	{Dec. 10, 1900 Jan. 8, 1901	62.7 62.9	144.8 145.2
26	Palace spring .....	{Dec. 11, 1900 Jan. 8, 1901	63.4 61.4	146.1 142.5
27	Tunnel spring .....	{Dec. 12, 1900 Jan. 8, 1901	..... 51.9	..... 125.4
28	Maurice spring .....	{Dec. 14, 1900 Jan. 8, 1901	..... 59.8	..... 139.6
29	Dripping spring .....	{Dec. 12, 1900 Jan. 8, 1901	57.1 57.8	134.8 136.0
30	Arch spring .....	{Dec. 15, 1900 Jan. 8, 1901	53.9 51.9	129.0 125.4
31	Haywood spring .....	{Dec. 19, 1900 Jan. 8, 1901	51.4 51.4	124.5 124.5
32	John W. Noble spring .....	{Dec. 17, 1900 Jan. 8, 1901	46.0 46.5	114.8 115.7
33	Lamar spring .....	{Dec. 18, 1900 Jan. 8, 1901	48.3 49.2	118.9 120.6
34	H. W. Wiley spring .....	{Dec. 20, 1900 Jan. 8, 1901	47.9 47.3	118.2 117.1
35	Ed Hardin spring .....	{Dec. 21, 1900 Jan. 8, 1901	39.0 43.0	102.2 109.4
36	Eisele spring .....	{Dec. 22, 1900 Jan. 8, 1901	48.9 48.8	120.0 119.8
37	Stevens spring .....	{Dec. 26, 1900 Jan. 8, 1901	52.9 52.6	127.2 126.7
38	Horse Shoe spring .....	{Dec. 27, 1900 Jan. 8, 1901	58.8 59.8	137.8 139.6
39	Army and Navy spring .....	{Dec. 28, 1900 Jan. 8, 1901	61.4 61.4	142.5 142.5
40	W. J. Little spring .....	{Dec. 31, 1900 Jan. 8, 1901	48.9 48.9	120.0 120.0
41	Mud spring .....	{Dec. 29, 1900 Jan. 8, 1901	46.8 48.3	116.2 118.9
42	Magnesia spring .....	{Jan. 2, 1901 Jan. 8, 1901	..... 58.3	..... 136.9
43	Reservoir spring .....	{Jan. 3, 1901 Jan. 8, 1901	46.3 46.1	115.3 115.0
44	Liver spring (cold) .....	{Jan. 4, 1901 Jan. 8, 1901	8.0 .....	46.4 .....
45	Kidney spring (cold) .....	{Jan. 5, 1901 Jan. 8, 1901	13.0 .....	55.4 .....
46	Fordyce spring .....	{Jan. 6, 1901 Jan. 8, 1901	51.5 51.5	124.7 124.7

*Flow of springs.*

Number.	Flow of springs per 24 hours.	Number.	Flow of springs per 24 hours.
	<i>Gallons.</i>		<i>Gallons.</i>
1 .....	28,800	27 .....	800
2+17 .....	10,800	28 .....	<sup>a</sup> 21,000
3 .....	19,938	29 .....	2,618
4 .....	3,600	30 .....	<sup>(b)</sup> .....
5 .....	17,280	31+33 .....	7,200
6 .....	32,400	32 .....	28,800
7+16 .....	18,514	34 .....	28,800
8 .....	<sup>a</sup> 2,000	35 .....	2,469
9+11+13 .....	51,840	36 .....	9,600
10 .....	18,514	37 .....	5,760
12 .....	524	38 .....	<sup>a</sup> 40,000
14 .....	8,640	39 .....	35,000
15 .....	201,600	40 .....	4,320
18 .....	<sup>a</sup> 35,000	41 .....	<sup>a</sup> 4,000
19 .....	13,292	42 .....	<sup>a</sup> 50,000
20 .....	3,677	43 .....	<sup>a</sup> 20,000
21 .....	1,152	44 .....	659
22 .....	1,723	45 .....	511
23+24 .....	10,800	46 .....	<sup>a</sup> 25,000
25 .....	<sup>a</sup> 35,000		
26 .....	25,847	Total .....	<sup>c</sup> 826,308

<sup>a</sup> Estimated.<sup>b</sup> Could not be estimated.<sup>c</sup> Excluding the two cold springs 44 and 45.

No. 1.—*Egg spring.*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis taken January 9, 1961. Temperature on November 7, 1900, was 61.9° C. and on January 8, 1901, was 61.7° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.16; oxygen, 1.18; carbon dioxide (free), 10.84; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.14; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	45.11	16.07	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.83	2.79	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	58.94	100
NO <sub>3</sub> (nitric acid radicle) .....	.88	.32	100
NO <sub>2</sub> (nitrous acid radicle) .....	Trace.	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.50	.89	800
Br (bromine) .....	Trace.	.....	3,200
I (iodine) .....	Trace.	.....	3,200
Fe <sup>l</sup> (iron and aluminum) .....	.24	.08	2,000
Al <sup>f</sup> .....	.....	.....	.....
Mn (manganese) .....	.36	.09	2,000
Ca (calcium) .....	46.09	16.78	2,000
Mg (magnesium) .....	4.81	1.72	2,000
K (potassium) .....	1.65	.59	4,000
Na (sodium) .....	4.52	1.62	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.302	.11	500
Total .....	280.792	100	.....
Total solids .....	200.00	.....	200
Albuminoid ammonia .....	.040	.....	500
Oxygen required .....	1.95	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.896	0.32
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.15	1.12
NaCl (sodium chloride) .....	.68	.24
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.59	4.13
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace	.....
NaNO <sub>3</sub> (sodium nitrate) .....	1.20	.43
NaNO <sub>2</sub> (sodium nitrite) .....	Trace.	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.62	.22
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	28.96	10.31
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	186.66	66.48
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.76	.27
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	1.16	.41
SiO <sub>2</sub> (silica) .....	45.11	16.07
Total .....	280.786	100

<sup>a</sup> Small amount.



No. 2.—*Arsenic spring.*

[Situated at base of Hot Springs Mountain, under wall of Arlington Hotel. Sample for mineral analysis taken January 9, 1901. Temperature on November 8, 1900, was 51.9° C., and January 8, 1901, was 53.9° C. This spring could not be reached, so the temperature was taken about 35 feet from the spring.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 7.97; oxygen, 3.34; carbon dioxide (free), 9.15; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.48; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	44.48	16.34	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	8.24	3.03	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	160.50	58.95	100
NO <sub>3</sub> (nitric acid radicle).....	.44	.17	100
NO <sub>2</sub> (nitrous acid radicle).....	Trace.	.....	100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.	.....	3,000
Cl (chlorine).....	2.50	.92	800
Br (bromine).....	Trace.	.....	3,200
I (iodine).....	Trace.	.....	3,200
Fe } (iron and aluminum).....	.24	.09	2,000
Al }			
Mn (manganese).....	Trace.	.....	2,000
Ca (calcium).....	44.64	16.40	2,000
Mg (magnesium).....	4.77	1.70	2,000
K (potassium).....	1.98	.74	4,000
Na (sodium).....	4.46	1.64	4,000
Li (lithium).....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium).....	.060	.02	500
Total.....	272.310	100	.....
Total solids.....	198.50	.....	200
Albuminoid ammonia.....	.001	.....	500
Oxygen required.....	.25	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Percent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.178	0.07
LiCl (lithium chloride).....	Trace.	.....
KCl (potassium chloride).....	3.77	1.38
NaCl (sodium chloride).....	.97	.36
KBr (potassium bromide).....	Trace.	.....
KI (potassium iodide).....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	12.09	4.44
MgSO <sub>4</sub> (magnesium sulphate).....	.09	.03
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate).....	.60	.22
NaNO <sub>2</sub> (sodium nitrite).....	Trace.	.....
Mg HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	28.60	10.50
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	180.79	66.39
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate).....	.76	.28
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	Trace.	.....
SiO <sub>2</sub> (silica).....	44.48	16.33
Total.....	272.328	100

<sup>a</sup> Small amount.

No. 3.—*Arlington spring.*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 8, 1900, was 61.7° C., and on January 8, 1901, was 61.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.57; oxygen, 2.27; carbon dioxide (free), 13.08; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
SiO <sub>2</sub> (silica) .....	44.89	15.96	c. c. 8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.76	2.78	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	59.58	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle) .....	.0007		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	(a)		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.50	.90	800
Br (bromine) .....	Trace.		3,200
I (iodine) .....	Trace.		3,200
Fe } (iron and aluminum) .....	.28	.11	2,000
Al }			
Mn (manganese) .....	.22	.08	2,000
Ca (calcium) .....	46.36	16.60	2,000
Mg (magnesium) .....	4.88	1.74	2,000
K (potassium) .....	1.65	.60	4,000
Na (sodium) .....	4.52	1.63	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.068	.02	500
Total .....	279.6287	100	
Total solids .....	202		200
Albuminoid ammonia .....	.010		500
Oxygen required .....	.25		200

\* Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.202	0.07
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.15	1.13
NaCl (sodium chloride) .....	1.44	.51
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.49	4.11
NaBO <sub>2</sub> (sodium metaborate) .....	(a)	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.0011	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.80	.29
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.38	10.50
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	187.78	67.10
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.40	.14
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.30	.11
SiO <sub>2</sub> (silica) .....	44.89	16.04
Total .....	279.8331	100

\* Small amount.



No. 4.—*Cliff Spring.*

[Situated at the base of Hot Springs Mountain under wall of Arlington Hotel. Sample for mineral analysis was taken January 9, 1901. Temperature on November 10, 1900, was 55.9° C., and on January 8, 1901, was 52.4° C. This spring could not be reached, so the temperature was taken about 8 feet from the spring.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 7.85; oxygen, 3.36; carbon dioxide (free), 12.52; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.46; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	43.55	16.03	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.63	3.17	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	160.50	59.03	100
NO <sub>3</sub> (nitric acid radicle) .....	.44	.16	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.38	.87	800
Br (bromine) .....	Trace.		3,200
I (iodine) .....	Trace.		3,200
Fe } (iron and aluminum) .....	.35	.13	2,000
Al }			
Mn (manganese) .....	.22	.08	2,000
Ca (calcium) .....	44.61	16.40	2,000
Mg (magnesium) .....	4.68	1.72	2,000
K (potassium) .....	2.01	.74	4,000
Na (sodium) .....	4.48	1.65	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.043	.02	500
Total .....	271.8943	100	.....
Total solids .....	197		200
Albuminoid ammonia .....			500
Oxygen required .....	.25		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.128	0.05
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.83	1.41
NaCl (sodium chloride) .....	.77	.28
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.40	4.56
MgSO <sub>4</sub> (magnesium sulphate) .....	.31	.11
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.60	.22
NaNO <sub>2</sub> (sodium nitrite) .....	.002	
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	27.82	10.23
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	180.67	66.45
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	1.11	.41
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.71	.26
SiO <sub>2</sub> (silica) .....	43.55	16.02
Total .....	271.900	100

<sup>a</sup> Small amount.

No. 5.—*Avenue spring.*

[Situating on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 12, 1900, was 61.4° C., and on January 8, 1901, was 61.9° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.24; oxygen, 2.20; carbon dioxide (free), 12.52; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.14; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
SiO <sub>2</sub> (silica) .....	44.31	15.84	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.85	2.81	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	59.62	100
NO <sub>3</sub> (nitric acid radicle) .....	.44	.15	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0022		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.38	.86	800
Br (bromine) .....	Trace.		3,200
I (iodine) .....	Trace.		3,200
Fe} (iron and aluminum) .....	.28	.10	2,000
Al}			
Mn (manganese) .....	.22	.07	2,000
Ca (calcium) .....	46.58	16.67	2,000
Mg (magnesium) .....	4.58	1.64	2,000
K (potassium) .....	1.65	.59	4,000
Na (sodium) .....	4.51	1.62	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.084	.03	500
Total .....	279.3862	100	
Total solids .....	201		200
Albuminoid ammonia .....	.005		500
Oxygen required .....	.95		200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.249	0.09
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.15	1.13
NaCl (sodium chloride) .....	1.17	.42
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.62	4.16
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.60	.22
NaNO <sub>2</sub> (sodium nitrite) .....	.0033	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.44	.16
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	27.58	9.87
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	188.65	67.52
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.89	.32
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.71	.25
SiO <sub>2</sub> (silica) .....	44.31	15.86
Total .....	279.3723	100

<sup>a</sup> Small amount.



No. 6.—*Boiler House spring.*

[Situated at base of Hot Springs Mountain in cellar of Arlington Hotel. Sample for mineral analysis was taken January 9, 1901. Temperature on November 13, 1900, was 57.5° C., and on January 8, 1901, was 58.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.10; oxygen, 3.06; carbon dioxide (free), 10.84; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.46; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica) .....	44.51	16.04	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.50	3.06	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	163.50	58.91	100
NO <sub>3</sub> (nitric acid radicle) .....	.75	.27	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.75	.99	800
Br (bromine) .....	Trace.	.....	3,200
I (iodine) .....	Trace.	.....	3,200
Fe } (iron and aluminum) .....	.21	.07	2,000
Al }			
Mn (manganese) .....	Trace.	.....	2,000
Ca (calcium) .....	46.25	16.66	2,000
Mg (magnesium) .....	4.88	1.76	2,000
K (potassium) .....	1.68	.61	4,000
Na (sodium) .....	4.50	1.62	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.025	.01	500
Total .....	277.5563	100	.....
Total solids .....	202	.....	200
Albuminoid ammonia .....	.001	.....	500
Oxygen required .....	.70	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.074	0.03
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.20	1.15
NaCl (sodium chloride) .....	1.33	.48
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.41	4.11
MgSO <sub>4</sub> (magnesium sulphate) .....	.99	.36
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	1.03	.37
NaNO <sub>2</sub> (sodium nitrite) .....	.002	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	28.18	10.16
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	185.90	67.01
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	.....
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.30	.11
Al <sub>2</sub> O <sub>3</sub> }		
CaSiO <sub>3</sub> (calcium silicate) .....	1.02	.37
SiO <sub>2</sub> (silica) .....	43.98	15.85
Total .....	277.416	100

<sup>a</sup> Small amount.

No. 7.—*Imperial spring (north).*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 14, 1900, was 60.1° C., and on January 8, 1901, was 60.8° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 7.75; oxygen, 2.53; carbon dioxide (free), 7.48; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.14; hydrogen sulphide, none.

Formula and name.	Parts per million	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	44.59	15.65	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.92	2.78	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	169.60	59.53	100
NO <sub>3</sub> (nitric acid radicle) .....	.33	.11	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0041	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	.86	.30	6,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.50	.88	800
Br (bromine) .....	Trace.	.....	3,200
I (iodine) .....	Trace.	.....	3,200
Fe (iron and aluminum) .....	.35	.12	2,000
Al .....	.18	.06	2,000
Mn (manganese) .....	47.23	16.58	2,000
Ca (calcium) .....	4.99	1.75	2,000
Mg (magnesium) .....	1.70	.59	4,000
K (potassium) .....	4.57	1.61	4,000
Na (sodium) .....	Trace.	.....	4,000
Li (lithium) .....	.116	.04	500
NH <sub>4</sub> (ammonium) .....			
Total .....	284.9401	100	.....
Total solids .....	202	.....	200
Albuminoid ammonia .....	.058	.....	500
Oxygen required .....	1.10	.....	200

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.344	0.12
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.24	1.14
NaCl (sodium chloride) .....	1.20	.42
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	10.85	3.81
MgSO <sub>4</sub> (magnesium sulphate) .....	.74	.26
NaBO <sub>2</sub> (sodium metaborate) .....	1.32	.46
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	.45	.16
NaNO <sub>2</sub> (sodium nitrite) .....	.0063	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.14	10.23
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	191.28	67.16
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	1.11	.39
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.58	.20
SiO <sub>2</sub> (silica) .....	44.59	15.65
Total .....	284.8503	100



No. 8.—*Crystal spring.*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 16, 1900, was 35.2° C., and on January 8, 1901, was 36.2° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.73; oxygen, 4.57; carbon dioxide (free), 13.13; carbon dioxide (set free from bicarbonates on evaporating to dryness), 32.21; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	46.28	15.99	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.88	2.72	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	172.60	59.64	100
NO <sub>3</sub> (nitric acid radicle) .....	.22	.07	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0012		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.50	.86	800
Br (bromine) .....	Trace.		3,200
I (iodine) .....	Trace.		3,200
Fe (iron and aluminum) .....	.28	.09	2,000
Al			
Mn (manganese) .....	Trace.		2,000
Ca (calcium) .....	48.35	16.72	2,000
Mg (magnesium) .....	4.90	1.70	2,000
K (potassium) .....	1.80	.62	4,000
Na (sodium) .....	4.54	1.57	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.065	.02	500
Total .....	289.4162	100	
Total solids .....	207.50		200
Albuminoid ammonia .....	.028		500
Oxygen required .....	.65		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.194	0.07
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.43	1.18
NaCl (sodium chloride) .....	1.22	.42
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.66	4.03
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.30	.10
NaNO <sub>2</sub> (sodium nitrate) .....	.0018	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.73	.25
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.50	10.19
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	195.82	67.65
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina) .....	.35	.12
Al <sub>2</sub> O <sub>3</sub>		
SiO <sub>2</sub> (silica) .....	46.28	15.99
Total .....	289.4858	100

<sup>a</sup> Small amount.

No. 9.—*Rector spring.*

[Situated at the base of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 17, 1900, was 61.1° C., and on January 8, 1901, was 62.4° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 7.58; oxygen, 3.02; carbon dioxide (free), 12.82; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.84; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	44.91	16.07	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.60	2.72	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	59.58	100
NO <sub>3</sub> (nitric acid radicle) .....	.09	.03	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.50	.90	800
Br (bromine) .....	Trace.		3,200
I (iodine) .....	Trace.		3,200
Fe} (iron and aluminum) .....	.21	.08	2,000
Al}			
Mn (maganese) .....	.11	.04	2,000
Ca (calcium) .....	46.18	16.53	2,000
Mg (magnesium) .....	4.97	1.77	2,000
K (potassium) .....	1.68	.60	4,000
Na (sodium) .....	4.64	1.66	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.062	.02	500
Total .....	279.4583	100	.....
Total solids .....	203		200
Albuminoid ammonia .....	.035		500
Oxygen required .....	.65		200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.184	0.07
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.20	1.15
NaCl (sodium chloride) .....	1.42	.51
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.25	4.02
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.12	.04
NaNO <sub>2</sub> (sodium nitrite) .....	.002	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	1.57	.56
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.92	10.70
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	186.45	66.67
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.30	.11
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.15	.05
CaSiO <sub>3</sub> (calcium silicate) .....	.41	.14
SiO <sub>2</sub> (silica) .....	44.70	15.98
Total .....	279.676	100

<sup>a</sup> Small amount.



No. 10.—*Cave spring.*

[Situating on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 19, 1900, was 57.4° C., and on January 8, 1901, was 57.2° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 7.80; oxygen, 3.13; carbon dioxide (free), 11.95; carbon dioxide (set free from bicarbonates on evaporating to dryness), 28.35; hydrogen sulphide, none.

Formula and name.	Parts per million.	Percent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	44.55	16.40	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.73	2.85	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	160.50	59.09	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle) .....	.0016		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>3</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.38	.88	800
Br (bromine) .....	Trace.		3,200
I (iodine) .....	Trace.		3,200
Fe (iron and aluminum) .....	.21	.08	2,000
Mn (manganese) .....	.22	.08	2,000
Ca (calcium) .....	45.07	16.60	2,000
Mg (magnesium) .....	4.94	1.82	2,000
K (potassium) .....	1.60	.59	4,000
Na (sodium) .....	4.37	1.60	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.031	.01	500
Total .....	271.6026	100	
Total solids .....	195.50		200
Albuminoid ammonia .....	.015		500
Oxygen required .....	.25		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.092	0.03
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.05	1.12
NaCl (sodium chloride) .....	1.44	.53
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.44	4.21
NaBO <sub>3</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.0024	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.33	.12
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.74	10.93
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	179.75	66.10
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina) .....	.30	.11
Al <sub>2</sub> O <sub>3</sub> .....	.30	.11
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.30	.11
CaSiO <sub>3</sub> (calcium silicate) .....	2.01	.74
SiO <sub>2</sub> (silica) .....	43.51	16
Total .....	271.9644	100

<sup>a</sup> Small amount.

No. 11.—*Little Iron spring (north).*

[Situated at the base of Hot Springs Mountain and empties into a reservoir. Sample for mineral analysis was taken January 9, 1901. Temperature on January 8, 1901, was 56.8° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.31; oxygen, 3.56; carbon dioxide (free), 1.88; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	47.44	17.24	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.28	3.00	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	160.50	58.35	100
NO <sub>3</sub> (nitric acid radicle) .....	.18	.07	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0012	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	(a)	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,500
Cl (chlorine) .....	2.71	.99	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine) .....	Trace.	.....	8,000
Fe } (iron and aluminum) .....	.12	.04	4,000
Al }			
Mn (manganese) .....	.11	.04	4,000
Ca (calcium) .....	43.84	15.95	4,000
Mg (magnesium) .....	4.98	1.81	4,000
K (potassium) .....	1.66	.60	4,000
Na (sodium) .....	5.18	1.88	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.095	.03	500
Total .....	275.0962	100	.....
Total solids .....	195.50	.....	200
Albuminoid ammonia .....	.049	.....	500
Oxygen required .....	.20	.....	200

<sup>a</sup>Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.282	0.10
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.16	1.15
NaCl (sodium chloride) .....	1.68	.61
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.25	4.45
NaBO <sub>2</sub> (sodium metaborate) .....	(a)	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	.25	.09
NaNO <sub>2</sub> (sodium nitrite) .....	.0018	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	1.75	.63
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.98	10.90
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	177.55	64.55
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.38	.14
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.35	.13
SiO <sub>2</sub> (silica) .....	47.44	17.25
Total .....	275.0738	100

<sup>a</sup>Small amount.



No. 12.—*Little Geyser spring.*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 22, 1900, was 36.2° C., and on January 8, 1901, was 36.2° C. This spring could not be reached, so the temperature was taken about 70 feet from the spring.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.83; oxygen, 4.61; carbon dioxide (free), 10.74; carbon dioxide (set free from bicarbonates on evaporating to dryness), 17.81; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica) .....	32.52	19.07	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	6.73	3.96	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	93.90	55.22	100
NO <sub>3</sub> (nitrate acid radicle) .....	.18	.10	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0008	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	.13	.08	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,500
Cl (chlorine) .....	2.43	1.43	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine) .....	Trace.	.....	8,000
Fe } (iron and aluminum) .....	.11	.06	4,000
Al }			
Mn (manganese) .....	Trace.	.....	9,000
Ca (calcium) .....	25.89	15.24	4,000
Mg (magnesium) .....	3.18	1.87	4,000
K (potassium) .....	1.31	.78	4,000
Na (sodium) .....	3.68	2.17	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.025	.02	500
Total .....	170.0858	100	.....
Total solids .....	129.50	.....	200
Albuminoid ammonia .....	.004	.....	500
Oxygen required .....	.20	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.074	0.04
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	2.50	1.46
NaCl (sodium chloride) .....	1.96	1.15
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	8.76	5.15
MgSO <sub>4</sub> (magnesium sulphate) .....	1.01	.59
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	.21	.12
NaNO <sub>3</sub> (sodium nitrate) .....	.25	.14
NaNO <sub>2</sub> (sodium nitrite) .....	.0012	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	17.94	10.56
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	104.53	61.46
Fe (HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.34	.20
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	.....
SiO <sub>2</sub> (silica) .....	32.52	19.13
Total .....	170.0952	100

<sup>a</sup> Small amount.

No. 13.—*Little Iron spring (south).*

[Situated at the base of Hot Springs Mountain and empties into a reservoir. Sample for mineral analysis was taken January 9, 1901. Temperature was 56.3° January 8, 1901.]

*Gases* (number of cubic centimeters per liter at 0°C. and 760 mm. pressure).—Nitrogen, 7.98; oxygen, 3.31; carbon dioxide (free), 3; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.46; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	46.17	16.40	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.35	2.96	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	59.11	100
NO <sub>3</sub> (nitric acid radicle) .....	.18	.06	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0012		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,500
Cl (chlorine) .....	2.57	.91	700
Br (bromine) .....	Trace.		8,000
I (iodine) .....	Trace.		8,000
Fe <sup>1</sup> (iron and aluminum) .....	.11	.04	4,000
Mn (manganese) .....	.12	.04	4,000
Ca (calcium) .....	46.22	16.41	4,000
Mg (magnesium) .....	4.93	1.75	4,000
K (potassium) .....	1.60	.57	4,000
Na (sodium) .....	4.87	1.73	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.043	.02	500
Total .....	281.6642	100	
Total solids .....	201.50		200
Albuminoid ammonia .....	.017		500
Oxygen required .....	.25		200

<sup>a</sup> Small amount.

## \* HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.128	0.04
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.05	1.08
NaCl (sodium chloride) .....	1.70	.60
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.36	4.39
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.25	.09
NaNO <sub>2</sub> (sodium nitrite) .....	.0018	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.44	.16
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.68	10.55
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	187.19	66.45
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.35	.12
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.38	.13
SiO <sub>2</sub> (silica) .....	46.17	16.39
Total .....	281.6998	100

<sup>a</sup> Small amount.



No. 14.—*Ral spring.*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature was 60.9° C., November 23, 1900, and 62.8° C., January 8, 1901.]

*Gases* (number of cubic centimeters per liter at 0°C. and 760 mm. pressure).—Nitrogen, 7.90; oxygen, 2.81; carbon dioxide (free), 15.32; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.02; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	45.17	16.12	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.95	2.84	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	59.44	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.	.....	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0033	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,500
Cl (chlorine) .....	2.36	.84	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine) .....	Trace.	.....	8,000
Fe } (iron and aluminum) .....	.11	.04	4,000
Al }			
Mn (manganese) .....	.27	.10	4,000
Ca (calcium) .....	46.21	16.50	4,000
Mg (magnesium) .....	4.84	1.76	4,000
K (potassium) .....	1.57	.56	4,000
Na (sodium) .....	4.98	1.78	4,000
Li (lithium) .....	Trace.	.....	4,000
Nh <sub>4</sub> (ammonium) .....	.048	.02	500
Total .....	280.0113	100	.....
Total solids .....	198.00	.....	200
Albuminoid ammonia .....	.010	.....	500
Oxygen required .....	.175	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.143	0.05
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	2.99	1.07
NaCl (sodium chloride) .....	1.39	.50
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.76	4.20
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	.....
NaNO <sub>2</sub> (sodium nitrite) .....	.005	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	2.26	.81
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.14	10.40
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	186.65	66.58
Fe <sub>2</sub> O <sub>3</sub> } (Ferric oxide and alumina) .....	.15	.05
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (manganic oxide) .....	.38	.14
CaSiO <sub>3</sub> (calcium silicate) .....	.35	.13
SiO <sub>2</sub> (silica) .....	44.99	16.07
Total .....	280.208	100

<sup>a</sup> Small amount.

No. 15.—*Big Iron spring.*

[Situated at the base of Hot Springs Mountain and empties into a reservoir. Sample for mineral analysis was taken January 9, 1901. Temperature was 63.9° C. on November 24, 1900, and 63.9° C. on January 7, 1901.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.80; oxygen, 3.79; carbon dioxide (free), 6.92; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.02; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	45.59	16.00	10,000
SO <sub>4</sub> (sulphuric acid radicle).....	7.84	2.75	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	168.10	59.02	100
NO <sub>3</sub> (nitric acid radicle).....	.44	.16	100
NO <sub>2</sub> (nitrous acid radicle).....	.0016	.....	100
PO <sub>4</sub> (phosphoric acid radicle).....	.05	.02	8,000
BO <sub>2</sub> (metaboric acid radicle).....	1.29	.45	6,750
AsO <sub>4</sub> (arsenic acid radicle).....	None.	.....	5,000
Cl (chlorine).....	2.53	.89	700
Br (bromine).....	Trace.	.....	8,000
I (iodine).....	Trace.	.....	8,000
Fl (fluorine).....	None.	.....	15,000
Fe (iron and aluminum).....	.19	.07	8,000
Al.....	.....	.....	.....
Mn (manganese).....	.34	.12	4,000
Ba (barium).....	Trace.	.....	15,000
Sr (strontium).....	Trace.	.....	6,000
Ca (calcium).....	46.93	16.48	4,000
Mg (magnesium).....	5.10	1.79	4,000
K (potassium).....	1.60	.56	4,000
Na (sodium).....	4.76	1.67	4,000
Li (lithium).....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium).....	.040	.02	500
Total.....	284.8016	100	.....
Total solids.....	198.50	.....	200
Albuminoid ammonia.....	.035	.....	500
Oxygen required.....	.55	.....	200

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.119	0.04
LiCl (lithium chloride).....	Trace.	.....
KCl (potassium chloride).....	3.05	1.07
NaCl (sodium chloride).....	1.65	.58
KBr (potassium bromide).....	Trace.	.....
KI (potassium iodide).....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	10.06	3.54
MgSO <sub>4</sub> (magnesium sulphate).....	1.30	.46
SrSO <sub>4</sub> (strontium sulphate).....	Trace.	.....
BaSO <sub>4</sub> (barium sulphate).....	Trace.	.....
NaBO <sub>2</sub> (sodium metaborate).....	1.98	.66
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	.08	.03
NaNO <sub>3</sub> (sodium nitrate).....	.60	.22
NaNO <sub>2</sub> (sodium nitrite).....	.0024	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	29.14	10.23
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	189.95	66.68
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	1.09	.38
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina).....	.27	.09
Al <sub>2</sub> O <sub>3</sub> .....	.....	.....
SiO <sub>2</sub> (silica).....	45.59	16.01
Total.....	284.8814	100



No. 16.—*Imperial spring (south).*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 26, 1900, was 60.8° C., and on January 8, 1901, was 60.9° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.39; oxygen, 2.49; carbon dioxide (free), 5.24; carbon dioxide (set free from bicarbonates on evaporating to dryness), 28.34; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	43.88	15.98	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.67	2.79	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	163.50	59.54	100
NO <sub>3</sub> (nitric acid radicle) .....	.27	.10	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0010	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,500
Cl (chlorine) .....	2.36	.86	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine) .....	Trace.	.....	8,000
Fe <sup>1</sup> Al <sup>1</sup> (iron and aluminum) .....	.09	.03	4,000
Mn (manganese) .....	.29	.10	4,000
Ca (calcium) .....	45.50	16.58	4,000
Mg (magnesium) .....	4.81	1.75	4,000
K (potassium) .....	1.60	.58	4,000
Na (sodium) .....	4.61	1.68	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.028	.01	500
Total .....	274.6090	100	.....
Total solids .....	189.00	.....	200
Albuminoid ammonia .....	None.	.....	500
Oxygen required .....	.25	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.083	0.03
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.05	1.11
NaCl (sodium chloride) .....	1.40	.51
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.35	4.13
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	.37	.13
NaNO <sub>2</sub> (sodium nitrite) .....	.0015	.....
NaHCO <sub>3</sub> (sodium bicarbonate) .....	1.02	.37
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.04	10.57
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	183.95	66.95
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.13	.05
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.40	.15
CaSiO <sub>3</sub> (calcium silicate) .....	.23	.08
SiO <sub>2</sub> (silica) .....	43.76	15.92
Total .....	274.7845	100

<sup>a</sup> Small amount.

No. 17.—*Arsenic spring (north).*

[Situated at the base of Hot Springs Mountain, just back of Arlington Hotel. Sample for mineral analysis was taken January 9, 1901. Temperature on November 28, 1900, was 55.4° C., and on January 8, 1901, was 56.4° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 7.82; oxygen, 3.21; carbon dioxide (free), 10.84; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.46; hydrogen sulphide, none.

Formula and name.	Parts per million.	Percent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	45.67	16.46	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.58	3.08	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	163.50	58.88	100
NO <sub>3</sub> (nitric acid radicle) .....	.44	.15	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0020		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	(a)		3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,500
Cl (chlorine) .....	2.36	.81	700
Br (bromine) .....	Trace.		8,000
I (iodine) .....	Trace.		8,000
Fe } (iron and aluminum) .....	.09	.03	4,000
Al }			
Mn (manganese) .....	Trace.		9,000
Ca (calcium) .....	45.40	16.36	4,000
Mg (magnesium) .....	4.70	1.69	4,000
K (potassium) .....	1.88	.69	4,000
Na (sodium) .....	5.12	1.84	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.037	.01	500
Total .....	277.7790	100	
Total solids .....	194.00		200
Albuminoid ammonia .....	.012		500
Oxygen required .....	.35		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.110	0.04
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.58	1.29
NaCl (sodium chloride) .....	.97	.35
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.70	4.57
NaBO <sub>2</sub> (sodium metaborate) .....	(a)	
Ca <sub>5</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.60	.22
NaNO <sub>2</sub> (sodium nitrite) .....	.003	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	1.68	.60
Mg(HCO <sub>3</sub> ) (magnesium bicarbonate) .....	28.30	10.19
Ca(HCO <sub>3</sub> ) (calcium bicarbonate) .....	183.87	66.19
Fe(HCO <sub>3</sub> ) (ferrous bicarbonate) .....	.29	.11
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	
SiO <sub>2</sub> (silica) .....	45.67	16.44
Total .....	277.773	100

<sup>a</sup> Small amount.



No. 18.—*Hitchcock spring.*

[Situated at the base of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on November 27, 1900, was 57.3° C., and on January 8, 1901, was 57.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 750 mm. pressure).—Nitrogen, 7.94; oxygen, 2.96; carbon dioxide (free), 12.52; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.46; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica) .....	44.74	16.02	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	10.63	3.80	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	162.00	57.99	100
NO <sub>3</sub> (nitric acid radicle) .....	1.55	.55	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0016	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,500
Cl (chlorine) .....	2.57	.92	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine) .....	Trace.	.....	8,000
Fe <sup>1</sup> (iron and aluminum) .....	.09	.03	4,000
Mn (manganese) .....	Trace.	.....	9,000
Ca (calcium) .....	46.04	16.48	4,000
Mg (magnesium) .....	4.94	1.76	4,000
K (potassium) .....	2.01	.72	4,000
Na (sodium) .....	4.79	1.71	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.057	.02	500
Total .....	279.4186	100	.....
Total solids .....	200.50	.....	200
Albuminoid ammonia .....	.025	.....	500
Oxygen required .....	.55	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.169	0.06
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.83	1.37
NaCl (sodium chloride) .....	1.05	.38
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.75	4.21
MgSO <sub>4</sub> (magnesium sulphate) .....	3.37	1.21
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	2.12	.76
NaNO <sub>2</sub> (sodium nitrite) .....	.0024	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	25.65	9.18
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	186.46	66.72
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.29	.10
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	.....
SiO <sub>2</sub> (silica) .....	44.74	16.01
Total .....	279.4314	100

<sup>a</sup> Small amount.

No. 19.—*Sumpter spring.*

[Situated at the base of Hot Springs Mountain under wall of a reservoir. Sample for mineral analysis was taken January 9, 1901. Temperature on December 1, 1900, was 56.4° C., and on January 8, 1901, was 56.1° C. This spring could not be reached, so the temperature was taken about 20 feet from the spring.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.20; oxygen, 3.25; carbon dioxide (free), 16.44; carbon dioxide (set free from bicarbonates on evaporating to dryness), 28.90; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	44.35	16.30	10,000
SO <sub>4</sub> (sulphuric acid radicle).....	8.75	3.21	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	159.00	58.45	100
NO <sub>3</sub> (nitric acid radicle).....	1.33	.49	100
NO <sub>2</sub> (nitrous acid radicle).....	.0010	.....	100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle).....	None.	.....	3,500
Cl (chlorine).....	2.57	.94	700
Br (bromine).....	Trace.	.....	8,000
I (iodine).....	Trace.	.....	8,000
Fe (iron and aluminum).....	.09	.03	4,000
Al	.....	.....	.....
Mn (manganese).....	Trace.	.....	9,000
Ca (calcium).....	44.72	16.43	4,000
Mg (magnesium).....	4.71	1.77	4,000
K (potassium).....	2.00	.70	4,000
Na (sodium).....	4.58	1.68	4,000
Li (lithium).....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium).....	.011	.....	500
Total.....	272.1120	100	.....
Total solids.....	192.50	.....	200
Albuminoid ammonia.....	None.	.....	500
Oxygen required.....	.30	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.033	0.01
LiCl (lithium chloride).....	Trace.	.....
KCl (potassium chloride).....	3.81	1.40
NaCl (sodium chloride).....	1.12	.41
KBr (potassium bromide).....	Trace.	.....
KI (potassium iodide).....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	11.13	4.09
MgSO <sub>4</sub> (magnesium sulphate).....	1.54	.57
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	.....
Ca <sub>3</sub> PO <sub>4</sub> (calcium phosphate).....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate).....	1.82	.67
NaNO <sub>2</sub> (sodium nitrite).....	.0015	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	26.49	9.75
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	181.12	66.67
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate).....	.29	.11
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	Trace.	.....
SiO <sub>2</sub> (silica).....	44.35	16.32
Total.....	271.7045	100

<sup>a</sup> Small amount.



No. 20.—*Superior spring (north).*

[Situating on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on December 3, 1900, was 46.3° C., and on January 8, 1901, was 44.5° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.97; oxygen, 3.75; carbon dioxide (free), 13.58; carbon dioxide (set free from bicarbonates on evaporating to dryness), 21.68; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	39.90	17.27	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.31	3.16	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	133.20	57.66	100
NO <sub>3</sub> (nitric acid radicle) .....	.31	.13	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0010	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	.13	.06	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,500
Cl (chlorine) .....	2.43	1.05	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine) .....	Trace.	.....	8,000
Fe } (iron and aluminum) .....	.09	.04	4,000
Al }			
Mn (manganese) .....	.11	.05	4,000
Ca (calcium) .....	37.43	16.20	4,000
Mg (magnesium) .....	4.23	1.83	4,000
K (potassium) .....	1.47	.64	4,000
Na (sodium) .....	4.40	1.90	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.013	.01	500
Total .....	231.0240	100	.....
Total solids .....	163.50	.....	200
Albuminoid ammonia .....	None.	.....	500
Oxygen required .....	.55	.....	200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.039	0.02
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	2.80	1.21
NaCl (sodium chloride) .....	1.76	.76
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	10.82	4.68
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	.21	.09
NaNO <sub>3</sub> (sodium nitrate) .....	.42	.18
NaNO <sub>2</sub> (sodium nitrite) .....	.0015	.....
NaHCO <sub>3</sub> (sodium bicarbonate) .....	.33	.14
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	25.47	11.01
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	148.35	64.12
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.13	.05
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.15	.06
CaSiO <sub>3</sub> (calcium silicate) .....	2.10	.91
SiO <sub>2</sub> (silica) .....	38.79	16.77
Total .....	231.3705	100

<sup>a</sup> Small amount.

No. 21.—*Alum spring.*

[Situated at the base of Hot Springs Mountain at side of Central avenue. Sample for mineral analysis was taken January 9, 1901. Temperature on December 4, 1900, was 43.3° C., and on January 8, 1901, was 46° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.57; oxygen, 3.55; carbon dioxide (free), 13.08; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Percent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	45.56	16.22	10,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.95	2.83	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	59.27	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,500
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,500
Cl (chlorine) .....	2.57	.92	700
Br (bromine) .....	Trace.		8,000
I (iodine) .....	Trace.		8,000
Fe <sup>l</sup> (iron and aluminum) .....	.09	.03	4,000
Mn (manganese) .....	.11	.04	4,000
Ca (calcium) .....	45.97	16.37	4,000
Mg (magnesium) .....	4.84	1.72	4,000
K (potassium) .....	1.65	.59	4,000
Na (sodium) .....	5.59	1.99	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.069	.02	500
Total .....	280.9003	100	
Total solids .....	201.00		200
Albuminoid ammonia .....	.014		500
Oxygen required .....	.70		200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.205	0.07
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.15	1.12
NaCl (sodium chloride) .....	1.53	.55
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.77	4.18
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.002	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	4.27	1.52
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.14	10.37
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	184.71	65.70
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina) .....	.13	.05
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.15	.05
CaSiO <sub>3</sub> (calcium silicate) .....	1.05	.37
SiO <sub>2</sub> (silica) .....	45.02	16.00
Total .....	281.127	100

<sup>a</sup> Small amount.



No. 22.—*Superior spring (south).*\*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis was taken January 9, 1901. Temperature on December 5, 1900, was 57.1° C., and on January 8, 1901, was 56.5° C.]

*Gases* (number of cubic centimeters per liter at 0° C and 760 mm. pressure).—Nitrogen, 8.49; oxygen, 3.04; carbon dioxide (free), 9.15; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.47; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	44.79	16.39	10,000
SO <sub>4</sub> (sulphuric acid radicle).....	8.03	2.94	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	162	59.26	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.	.....	100
NO <sub>2</sub> (nitrous acid radicle).....	.0055	.....	100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle).....	None.	.....	3,500
Cl (chlorine) .....	2.43	.89	700
Br (bromine) .....	Trace.	.....	8,000
I (iodine).....	Trace.	.....	8,000
Fe } (iron and aluminum).....	.09	.03	4,000
Al }			
Mn (manganese) .....	.18	.07	4,000
Ca (calcium) .....	44.73	16.36	4,000
Mg (magnesium).....	4.76	1.74	4,000
K (potassium).....	1.64	.60	4,000
Na (sodium).....	4.67	1.71	4,000
Li (lithium).....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium).....	.025	.01	500
Total .....	273.3505	100	.....
Total solids.....	194.50	.....	200
Albuminoid ammonia.....	.022	.....	500
Oxygen required.....	.35	.....	200

\*Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.074	0.02
LiCl (lithium chloride).....	Trace.	.....
KCl (potassium chloride).....	3.13	1.14
NaCl (sodium chloride) .....	1.47	.54
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.88	4.35
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	.....
NaNO <sub>2</sub> (sodium nitrite).....	.0083	.....
NaHCO <sub>3</sub> (sodium bicarbonate) .....	.88	.32
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	28.66	10.47
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	181.56	66.42
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.29	.16
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	.58	.21
SiO <sub>2</sub> (silica).....	44.79	16.37
Total.....	273.3223	100

\*Small amount.

No. 23.—*Twin spring (north).*

[Situated on the side of Hot Springs Mountain in the roadway. Sample for mineral analysis was taken January 9, 1901. Temperature on December 6, 1900, was 62.° C., and on January 8, 1901, was 62.4° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.36; oxygen, 2.68; carbon dioxide (free), 10.84; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.14; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	46.25	16.22	10,000
SO <sub>4</sub> (sulphuric acid radicle).....	7.97	2.80	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	169.60	59.48	100
NO <sub>3</sub> (nitric acid radicle).....	Trace.	.....	100
NO <sub>2</sub> (nitrous acid radicle).....	.0010	.....	100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )	.....	3,500
AsO <sub>4</sub> (arsenic acid radicle).....	None.	.....	3,500
Cl (chlorine).....	2.43	.85	700
Br (bromine).....	Trace.	.....	8,000
I (iodine).....	Trace.	.....	8,000
Fe } (iron and aluminum).....	.09	.03	4,000
Al }			
Mn (manganese).....	.16	.06	4,000
Ca (calcium).....	46.92	16.46	4,000
Mg (magnesium).....	4.82	1.69	4,000
K (potassium).....	1.74	.61	4,000
Na (sodium).....	5.11	1.79	4,000
Li (lithium).....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium).....	.032	.01	500
Total.....	285.1230	100	.....
Total solids.....	200	.....	200
Albuminoid ammonia.....	.001	.....	500
Oxygen required.....	.25	.....	200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.095	0.03
LiCl (lithium chloride).....	Trace.	.....
KCl (potassium chloride).....	3.32	1.16
NaCl (sodium chloride).....	1.30	.46
KBr (potassium bromide).....	Trace.	.....
KI (potassium iodide).....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	11.79	4.13
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate).....	Trace.	.....
NaNO <sub>2</sub> (sodium nitrite).....	.0015	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate).....	2.84	.99
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	29.02	10.18
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	190.03	66.63
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	.33	.12
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina).....	.13	.05
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>3</sub> O <sub>4</sub> (mangano-manganic oxide).....	.08	.03
SiO <sub>2</sub> (silica).....	46.25	16.22
Total.....	285.1865	100

<sup>a</sup> Small amount.



No. 24.—*Twin spring (south).*

[Situated on side of Hot Springs Mountain at side of road. Sample for mineral analysis taken May 19, 1901. Temperature on December 7, 1900, was 62.3° C., and on January 8, 1901, was 60.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.03; oxygen, 3.19; carbon dioxide (free), 4.12; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.14; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	46.85	16.44	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.81	2.74	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	168.80	59.25	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle) .....	.0008		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.83	.99	600
Br (bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe. } (iron and aluminum) .....	.22	.08	7,500
Al. }			
Mn (manganese) .....	.15	.05	7,500
Ca (calcium) .....	46.75	16.41	2,000
Mg (magnesium) .....	4.92	1.73	2,000
K (potassium) .....	1.74	.61	4,000
Na (sodium) .....	4.78	1.69	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.035	.01	500
Total .....	284.8858	100	
Total solids .....	224.50		200
Albuminoid ammonia .....	.002		500
Oxygen required .....	.15		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.104	0.04
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.31	1.16
NaCl (sodium chloride) .....	1.96	.69
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.56	4.06
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.0012	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.95	.33
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.62	10.39
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	189.34	66.47
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.70	.24
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.48	.17
SiO <sub>2</sub> (silica) .....	46.85	16.45
Total .....	284.8752	100

<sup>a</sup> Small amount.

No. 25.—*Old Hale spring.*

[Situated at base of Hot Springs Mountain, under Hale bath house. Sample for mineral analysis taken May 19, 1901. Temperature on December 10, 1900, was 62.7° C., and on January 8, 1901, was 62.9° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.72; oxygen, 3.01; carbon dioxide (free), 9.72; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.14; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica).....	47.31	16.72	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	7.80	2.76	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	166.50	58.87	100
NO <sub>3</sub> (nitric acid radicle).....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle).....	.0007		100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	2.50	.88	600
Br (bromine).....	Trace.		5,400
I (iodine).....	Trace.		5,400
Fe <sup>1</sup> (iron and aluminum).....	.19	.07	7,500
Al <sup>1</sup>			
Mn (manganese).....	.29	.10	7,500
Ca (calcium).....	46.82	16.55	2,000
Mg (magnesium).....	5.01	1.77	2,000
K (potassium).....	1.69	.60	4,000
Na (sodium).....	4.73	1.67	4,000
Li (lithium).....	Trace.		4,000
NH <sub>4</sub> (ammonium).....	.028	.01	500
Total.....	282.8687	100	
Total solids.....	199.50		200
Albuminoid ammonia.....	.002		500
Oxygen required.....	.30		200

<sup>a</sup>Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.083	0.03
LiCl (lithium chloride).....	Trace.	
KCl (potassium chloride).....	3.22	1.13
NaCl (sodium chloride).....	1.50	.53
KBr (potassium bromide).....	Trace.	
KI (potassium iodide).....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	11.54	4.07
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	
NaNO <sub>3</sub> (sodium nitrate).....	Trace.	
NaNO <sub>2</sub> (sodium nitrite).....	.0010	
Na(HCO <sub>3</sub> ) (sodium bicarbonate).....	1.46	.51
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	30.16	10.64
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	186.29	65.75
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina).....	.27	.10
Al <sub>2</sub> O <sub>3</sub>		
Mn <sub>3</sub> O <sub>4</sub> (mangano-manganic oxide).....	.40	.14
CaSiO <sub>3</sub> (calcium silicate).....	2.38	.84
SiO <sub>2</sub> (silica).....	46.08	16.26
Total.....	283.3840	100

<sup>a</sup>Small amount.



No. 26.—*Palace spring.*

[Situated at base of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 11, 1900, was 63.4° C., and on January 8, 1901, was 61.4° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.84; oxygen, 3.02; carbon dioxide (free), 8.60; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	47.86	16.90	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.82	2.76	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	58.80	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle) .....	.0008		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.50	.88	600
Br bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe } (iron and aluminum) .....	.19	.07	7,500
Al }			
Mn (manganese) .....	Trace.		7,500
Ca (calcium) .....	46.75	16.52	2,000
Mg (magnesium) .....	4.99	1.76	2,000
K (potassium) .....	1.74	.61	4,000
Na (sodium) .....	4.80	1.69	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.021	.01	500
Total .....	283.1718	100	
Total solids .....	201.50		200
Albuminoid ammonia .....	.005		500
Oxygen required .....	.35		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.062	0.03
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.31	1.17
NaCl (sodium chloride) .....	1.43	.50
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.58	4.08
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.0012	
NaHCO <sub>3</sub> (sodium bicarbonate) .....	1.75	.61
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	30.04	10.60
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	186.14	65.65
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.27	.09
Al <sub>2</sub> O <sub>3</sub> }		
CaSiO <sub>3</sub> (calcium silicate) .....	2.30	.81
SiO <sub>2</sub> (silica) .....	46.67	16.46
Total .....	283.5532	100

<sup>a</sup> Small amount.

No. 27.—*Tunnel spring.*

[Situated at base of Hot Springs Mountain in a cluster of springs. Sample for mineral analysis taken May 19, 1901. Temperature on January 8, 1901, was 51.9° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9; oxygen, 3.71; carbon dioxide (free), 8.60; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	49.95	19.31	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	7.98	3.08	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	146.70	56.70	100
NO <sub>3</sub> (nitric acid radicle).....	.22	.09	100
NO <sub>2</sub> (nitrous acid radicle).....	.0010		100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	2.58	1	600
Br (bromine).....	Trace.		5,400
I (iodine).....	Trace.		5,400
Fe } (iron and aluminum).....	.16	.06	7,500
Al }			
Mn (manganese).....	.14	.05	7,500
Ca (calcium).....	39.61	15.32	2,000
Mg (magnesium).....	4.95	1.91	2,000
K (potassium).....	1.73	.67	4,000
Na (sodium).....	4.66	1.80	4,000
Li (lithium).....	Trace.		4,000
NH <sub>4</sub> (ammonium).....	.037	.01	500
Total.....	258.7180	100	
Total solids.....	188.50		200
Albuminoid ammonia.....	.010		500
Oxygen required.....	.45		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.110	0.04
LiCl (lithium chloride).....	Trace.	
KCl (potassium chloride).....	3.29	1.27
NaCl (sodium chloride).....	1.58	.61
KBr (potassium bromide).....	Trace.	
KI (potassium iodide).....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	11.81	4.56
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	
NaNO <sub>3</sub> (sodium nitrate).....	.30	.12
NaNO <sub>2</sub> (sodium nitrite).....	.0015	
Na(HCO <sub>3</sub> ) (sodium bicarbonate).....	.47	.18
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	29.80	11.52
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	160.42	62.02
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate).....	.51	.20
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	.45	.17
SiO <sub>2</sub> (silica).....	49.95	19.31
Total.....	258.6915	100

<sup>a</sup> Small amount.



No. 28.—*Maurice spring.*

[situated at base of Hot Springs Mountain in a cluster of springs. Sample for mineral analysis taken May 19, 1901. Temperature on January 8, 1901, was 59.8°C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.73; oxygen, 2.46; carbon dioxide (free), 10.58; Carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.27; hydrogen sulphide, none.

Formula and name.	Parts per million.	Percent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	47.41	16.91	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	7.80	2.78	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	165	58.85	100
NO <sub>3</sub> (nitric acid radicle).....	.27	.10	100
NO <sub>2</sub> (nitrous acid radicle).....	.0008		100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	2.58	.92	600
Br (bromine).....	Trace.		5,400
I (iodine).....	Trace.		5,400
Fe } (iron and aluminum).....	.21	.07	7,500
Al }			
Mn (manganese).....	.15	.05	7,500
Ca (calcium).....	45.47	16.21	2,000
Mg (magnesium).....	4.82	1.72	2,000
K (potassium).....	1.76	.63	4,000
Na (sodium).....	4.89	1.74	4,000
Li (lithium).....	Trace.		4,000
NH <sub>4</sub> (ammonium).....	.061	.02	500
Total.....	280.4218	100	
Total solids.....	198.50		200
Albuminoid ammonia.....	.043		500
Oxygen required.....	1.05		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.181	0.06
LiCl (lithium chloride).....	Trace.	
KCl (potassium chloride).....	3.36	1.20
NaCl (sodium chloride).....	1.41	.50
KBr (potassium bromide).....	Trace.	
KI (potassium iodide).....	Trace.	
Na <sub>2</sub> SO (sodium sulphate).....	11.54	4.12
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	
NaNO <sub>3</sub> (sodium nitrate).....	.37	.13
NaNO <sub>2</sub> (sodium nitrite).....	.0012	
Na(HCO <sub>3</sub> ) (sodium bicarbonate).....	1.82	.65
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	29.02	10.35
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	184.15	65.67
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate).....	.67	.24
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	.48	.17
SiO <sub>2</sub> (silica).....	47.41	16.91
Total.....	280.4122	100

<sup>a</sup> Small amount.

No. 29.—*Dripping spring.*

[Situated at base of Hot Springs Mountain. Flows from side of cliff. Sample for mineral analysis taken May 19, 1901. Temperature on December 13, 1900, was 57.1° C., and on January 8, 1901, was 57.8° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.18; oxygen, 3.93; carbon dioxide (free), 3.86; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.28; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	48.02	17.03	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.64	2.71	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	165.00	58.52	100
NO <sub>3</sub> (nitric acid radicle) .....	.22	.08	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0003	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	.80	.28	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.58	.91	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe } (iron and aluminum) .....	.22	.08	7,500
Al }			
Mn (manganese) .....	Trace.	.....	7,500
Ca (calcium) .....	45.97	16.30	2,000
Mg (magnesium) .....	4.80	1.70	2,000
K (potassium) .....	1.67	.59	4,000
Na (sodium) .....	5.09	1.80	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.010	.....	500
Total .....	282.0203	100	.....
Total solids .....	196.50	.....	200
Albuminoid ammonia .....	None.	.....	500
Oxygen required .....	.25	.....	200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.030	0.01
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.18	1.13
NaCl (sodium chloride) .....	1.73	.61
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.30	4.01
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	1.31	.46
NaNO <sub>3</sub> (sodium nitrate) .....	.30	.11
NaNO <sub>2</sub> (sodium nitrite) .....	.0005	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	2.44	.86
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	28.90	10.25
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	184.11	65.28
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.70	.25
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	.....
SiO <sub>2</sub> (silica) .....	48.02	17.03
Total .....	282.0205	100

<sup>a</sup> Small amount.

No. 30.—*Arch spring.*

[Situated at the base of Hot Springs Mountain, in arch of creek under Central avenue. Sample for mineral analysis taken May 19, 1901. Temperature December 15, 1900, was 53.9° C., and on January 8, 1901, was 51.9° C.]

*Gases* (number of cubic centimeters per liter at 0° C and 760 mm. pressure).—Nitrogen, 8.55; oxygen, 3.52; carbon dioxide (free), 5.55; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.27; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica) .....	50.90	18.59	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.50	2.74	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	157.50	57.53	100
NO <sub>3</sub> (nitric acid radicle) .....	.44	.16	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0020		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>3</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.67	.97	600
Br (bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe (iron and aluminum) .....	.12	.04	7,500
Al .....			
Mn (manganese) .....	Trace.		7,500
Ca (calcium) .....	43.00	15.72	2,000
Mg (magnesium) .....	4.92	1.80	2,000
K (potassium) .....	1.72	.63	4,000
Na (sodium) .....	4.99	1.82	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.011		500
Total .....	273.7730	100	
Total solids .....	192.50		200
Albuminoid ammonia .....	.009		500
Oxygen required .....	.75		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.033	0.01
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.28	1.20
NaCl (sodium chloride) .....	1.80	.65
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.10	4.05
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.60	.22
NaNO <sub>2</sub> (sodium nitrite) .....	.0030	
NaHCO <sub>3</sub> (sodium bicarbonate) .....	1.90	.70
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.62	10.82
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	174.16	63.62
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.38	.14
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	
SiO <sub>2</sub> (silica) .....	50.90	18.59
Total .....	273.7760	100

<sup>a</sup> Small amount.



No. 31.—*Haywood spring.*

[Situated on side of Hot Spring Mountain, near road. Sample for mineral analysis taken May 19, 1901. Temperature on December 19, 1900, was 51.4° C., and on January 8, 1901, was 51.4° C.]

*Gases* (number of cubic centimeters per liter at 0° C and 760 mm. pressure).—Nitrogen, 9.98; oxygen, 2.21; carbon dioxide (free), 14.75; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.45; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	47.40	17.04	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.78	3.16	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	162.00	58.22	100
NO <sub>3</sub> (nitric acid radicle) .....	.34	.12	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0008	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.67	.96	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe } (iron and aluminum) .....	.19	.07	7,500
Al }			
Mn (manganese) .....	.25	.09	7,500
Ca (calcium) .....	45.45	16.34	2,000
Mg (magnesium) .....	4.72	1.70	2,000
K (potassium) .....	1.65	.60	4,000
Na (sodium) .....	4.69	1.68	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.042	.02	500
Total .....	278.1828	100	.....
Total solids .....	199.00	.....	200
Albuminoid ammonia .....	.011	.....	500
Oxygen required .....	.35	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.125	0.04
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.15	1.13
NaCl (sodium chloride) .....	1.80	.65
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.87	4.27
MgSO <sub>4</sub> (magnesium sulphate) .....	.95	.34
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	.47	.17
NaNO <sub>2</sub> (sodium nitrite) .....	.0012	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	27.27	9.80
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	184.07	66.18
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.81	.29
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.27	.09
Al <sub>2</sub> O <sub>3</sub> }		
SiO <sub>2</sub> (silica) .....	47.40	17.04
Total .....	278.1862	100

<sup>a</sup> Small amount.

No. 32.—*John W. Noble spring.*

[Situated on the side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 17, 1900, was 46° C., and on January 8, 1901, was 46.5° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.10; oxygen, 3.66; carbon dioxide (free), 8.04; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.47; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	48.27	17.56	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.29	3.02	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	159	57.84	100
NO <sub>3</sub> (nitric acid radicle) .....	.34	.12	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>3</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.50	.91	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe <sup>1</sup> (iron and aluminum) .....	.19	.07	7,500
Mn (manganese) .....	.12	.04	7,500
Ca (calcium) .....	44.75	16.28	2,000
Mg (magnesium) .....	4.73	1.72	2,000
K (potassium) .....	1.72	.63	4,000
Na (sodium) .....	4.94	1.80	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.023	.01	500
Total .....	274.8743	100	.....
Total solids .....	200	.....	200
Albuminoid ammonia .....	.007	.....	500
Oxygen required .....	.55	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Percent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.069	0.03
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.28	1.19
NaCl (sodium chloride) .....	1.47	.53
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.27	4.46
NaBO <sub>3</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	.47	.17
NaNO <sub>2</sub> (sodium nitrite) .....	.0019	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.93	.34
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	28.47	10.34
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	178.70	64.93
Fe <sub>2</sub> O <sub>3</sub> <sup>1</sup> (ferric oxide and alumina) .....	.27	.09
Al <sub>2</sub> O <sub>3</sub> <sup>1</sup> .....	.....	.....
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.17	.06
CaSiO <sub>3</sub> (calcium silicate) .....	1.83	.66
SiO <sub>2</sub> (silica) .....	47.32	17.20
Total .....	275.2509	100

<sup>a</sup> Small amount.

No. 33.—*Lamar spring.*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 18, 1900, was 48.3° C., and January 8, 1901, was 49.2° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.84; oxygen, 2.82; carbon dioxide (free), 6.36; carbon dioxide (set free from bicarbonates on evaporating to dryness), 31.15; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	49.60	17.52	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	8.53	3.01	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	165.00	58.29	100
NO <sub>3</sub> (nitric acid radicle).....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle).....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	2.50	.88	600
Br (bromine).....	Trace.		5,400
I (iodine).....	Trace.		5,400
Fe <sup>1</sup> (iron and aluminum).....	.22	.08	7,500
Mn (manganese).....	.15	.05	7,500
Ca (calcium).....	45.94	16.23	2,000
Mg (magnesium).....	4.80	1.70	2,000
K (potassium).....	1.68	.59	4,000
Na (sodium).....	4.65	1.64	4,000
Li (lithium).....	Trace.		4,000
NH (ammonium).....	.042	.01	500
Total.....	283.1133	100	-----
Total solids.....	202.50		200
Albuminoid ammonia.....	.022		500
Oxygen required.....	.65		200

<sup>a</sup>Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.125	0.04
LiCl (lithium chloride).....	Trace.	
KCl (potassium chloride).....	3.20	1.13
NaCl (sodium chloride).....	1.48	.52
KBr (potassium bromide).....	Trace.	
KI (potassium iodide).....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	12.55	4.43
MgSO <sub>4</sub> (magnesium sulphate).....	.06	.02
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	
NaNO <sub>3</sub> (sodium nitrate).....	Trace.	
NaNO <sub>2</sub> (sodium nitrite).....	.0019	
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	28.84	10.19
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	186.08	65.73
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate).....	.70	.25
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	.48	.17
SiO <sub>2</sub> (silica).....	49.60	17.52
Total.....	283.1169	100

<sup>a</sup>Small amount.



No. 34.—*H. W. Wiley spring.*

[Situatd on the side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 20, 1900, was 47.9° C., and on January 8, 1901, was 47.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 10.34; oxygen, 2.07; carbon dioxide (free), 11.40; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.46; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica).....	46.90	16.82	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	8.08	2.90	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	163.50	58.73	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle).....	.0016		100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.		2,000
BO <sub>3</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	2.67	.96	600
Br (bromine).....	Trace.		5,400
I (iodine).....	Trace.		5,400
Fe } (iron and aluminum).....	.24	.09	7,500
Al }			
Mn (manganese) .....	.04	.01	7,500
Ca (calcium).....	45.68	16.42	2,000
Mg (magnesium).....	4.73	1.70	2,000
K (potassium).....	1.69	.61	4,000
Na (sodium).....	4.84	1.74	4,000
Li (lithium).....	Trace.		4,000
NH <sub>4</sub> (ammonium).....	.045	.02	500
Total .....	278.4166	100	
Total solids.....	196		200
Albuminoid ammonia.....	.017		500
Oxygen required .....	.55		200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.133	0.05
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) ..	3.22	1.15
NaCl (sodium chloride).....	1.73	.62
KBr (potassium bromide).....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	11.96	4.29
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.0024	
Na(HCO <sub>3</sub> ) (sodium bicarbonate).....	1.02	.37
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	28.47	10.23
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	184.60	66.27
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina).....	.34	.12
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.05	.02
CaSiO <sub>3</sub> (calcium silicate).....	.29	.10
SiO <sub>2</sub> (silica) .....	46.75	16.78
Total .....	278.5654	100

<sup>a</sup> Small amount.

No. 35.—*Ed Hardin spring.*

[Situated at base of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on January 8, 1901, was 43° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.97; oxygen, 2.76; carbon dioxide (free), 14.20; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.02; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	46.57	16.58	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.49	2.67	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	165.00	58.77	100
NO <sub>3</sub> (nitric acid radicle) .....	1.33	.47	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.50	.89	600
Br (bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe <sup>1</sup> } (iron and aluminum) .....	.19	.07	7,500
Al <sup>1</sup> }			
Mn (manganese) .....	.20	.07	7,500
Ca (calcium) .....	46.32	16.49	2,000
Mg (magnesium) .....	4.79	1.71	2,000
K (potassium) .....	1.70	.61	4,000
Na (sodium) .....	4.65	1.66	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.023	.01	500
Total .....	280.7643	100	
Total solids .....	202		200
Albuminoid ammonia .....	.010		500
Oxygen required .....	.25		200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.068	0.02
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.24	1.15
NaCl (sodium chloride) .....	1.50	.53
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.01	3.92
MgSO <sub>4</sub> (magnesium sulphate) .....	.06	.02
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	1.82	.65
NaNO <sub>2</sub> (sodium nitrite) .....	.0019	
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	28.78	10.24
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	187.23	66.65
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.27	.10
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>3</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.28	.10
CaSiO <sub>3</sub> (calcium silicate) .....	.26	.09
SiO <sub>2</sub> (silica) .....	46.44	16.53
Total .....	280.9599	100

<sup>a</sup> Small amount.

No. 36.—Eisele spring.

[Situatd on the side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 22, 1900, was 48.9° C. and on January 8, 1901, was 48.8° C.]

Gases (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 8.61; oxygen, 3.02; carbon dioxide (free), 8.04; carbon dioxide (set free from bicarbonates on evaporating to dryness), 29.47; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica).....	48.84	17.30	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	8.71	3.08	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	163.50	57.90	100
NO <sub>3</sub> (nitric acid radicle).....	.78	.28	100
NO <sub>2</sub> (nitrous acid radicle).....	.0007	.....	100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle).....	(a)	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.	.....	3,000
Cl (chlorine).....	2.58	.91	600
Br (bromine).....	Trace.	.....	5,400
I (iodine).....	Trace.	.....	5,400
Fe <sub>2</sub> Al <sub>3</sub> (iron and aluminum).....	.19	.07	7,500
Mn (manganese).....	.11	.04	7,500
Ca (calcium).....	46.33	16.41	2,000
Mg (magnesium).....	4.92	1.74	2,000
K (potassium).....	1.68	.59	4,000
Na (sodium).....	4.70	1.67	4,000
Li (lithium).....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium).....	.023	.01	500
Total.....	282.3637	100	.....
Total solids.....	208	.....	200
Albuminoid ammonia.....	.005	.....	500
Oxygen required.....	.20	.....	200

\* Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.068	0.02
LiCl (lithium chloride).....	Trace.	.....
KCl (potassium chloride).....	3.20	1.13
NaCl (sodium chloride).....	1.70	.60
KBr (potassium bromide).....	Trace.	.....
KI (potassium iodide).....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	11.50	4.07
MgSO <sub>4</sub> (magnesium sulphate).....	1.18	.42
NaBO <sub>2</sub> (sodium metaborate).....	(a)	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate).....	1.07	.38
NaNO <sub>2</sub> (sodium nitrite).....	.0010	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	28.18	9.97
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	185.90	65.77
Fe <sub>2</sub> O <sub>3</sub> Al <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina).....	.27	.10
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide).....	.15	.05
CaSiO <sub>3</sub> (calcium silicate).....	1.23	.43
SiO <sub>2</sub> (silica).....	48.21	17.06
Total.....	282.6590	100

\* Small amount.



No. 37.—*Stevens springs.*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis was taken May 19, 1901. Temperature on December 26, 1900, was 52.9° C., and on January 8, 1901, was 52.6° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 10.84; oxygen, 2.17; carbon dioxide (free), 13.64; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	46.65	15.70	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	15.78	5.31	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	169.60	57.12	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.		100
NO <sub>2</sub> (nitrous acid radicle) .....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	2.67	.90	600
Br (bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe <sup>1</sup> Al <sup>1</sup> (iron and aluminum) .....	.14	.05	9,000
Mn (manganese) .....	.08	.03	9,000
Ca (calcium) .....	49.93	16.80	2,000
Mg (magnesium) .....	5.07	1.71	2,000
K (potassium) .....	1.76	.59	4,000
Na (sodium) .....	5.28	1.78	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.036	.01	500
Total .....	296.9973	100	
Total solids .....	213		100
Albuminoid ammonia .....	.013		500
Oxygen required .....	.40		200

<sup>a</sup> Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.107	0.04
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.35	1.13
NaCl (sodium chloride) .....	1.67	.56
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	14.25	4.80
MgSO <sub>4</sub> (magnesium sulphate) .....	7.71	2.59
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	
NaNO <sub>2</sub> (sodium nitrite) .....	.0020	
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	21.13	7.11
Fe <sub>2</sub> O <sub>3</sub> (ferrie oxide and alumina) .....	201.81	67.92
Al <sub>2</sub> O <sub>3</sub> (ferrie oxide and alumina) .....	.20	.07
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.11	.04
CaSiO <sub>3</sub> (calcium silicate) .....	.29	.09
SiO <sub>2</sub> (silica) .....	46.50	15.65
Total .....	297.1290	100

<sup>a</sup> Small amount.

No. 38.—*Horse Shoe spring.*

[Situated at base of Hot Springs Mountain, under Horse Shoe bath house. Sample for mineral analysis taken May 19, 1901. Temperature on December 27, 1900, was 58.8° C., and on January 8, 1901, was 59.8° C.]

(*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.54; oxygen, 2.46; carbon dioxide (free), 10.02; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.84; hydrogen sulphide, none.

Formula and name.	Parts per millions.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	49.81	17.14	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.86	2.71	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	171.10	58.89	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.	.....	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0005	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle.) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.50	.86	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe } (iron and aluminum) .....	.26	.09	9,000
Al }			
Mn (manganese) .....	.27	.09	9,000
Ca (calcium) .....	46.61	16.05	2,000
Mg (magnesium) .....	5.07	1.74	2,000
K (potassium) .....	1.60	.55	4,000
Na (sodium) .....	5.42	1.87	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.030	.01	500
Total .....	290.5305	100	.....
Total solids .....	202	.....	100
Albuminoid ammonia .....	.003	.....	500
Oxygen required .....	.30	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.090	0.03
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.05	1.05
NaCl (sodium chloride) .....	1.63	.56
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.63	4.00
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	.....
NaNO <sub>2</sub> (sodium nitrite) .....	.0008	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	3.68	1.27
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	30.52	10.50
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	188.77	64.96
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate) .....	.32	.11
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.87	.30
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.23	.08
Al <sub>2</sub> O <sub>3</sub> }		
SiO <sub>2</sub> (silica) .....	49.81	17.14
Total .....	290.6008	100

<sup>a</sup> Small amount.

No. 39.—*Army and Navy spring.*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 28, 1900, was 61.4° C., and January 8, 1901, was 61.4° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.70; oxygen, 2.37; carbon dioxide (free), 17; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	50.51	17.12	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	9.41	3.19	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	169.60	57.52	100
NO <sub>3</sub> (nitric acid radicle) .....	1.33	.45	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0030		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	3.33	1.13	600
Br (bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe <sup>1</sup> Al <sup>1</sup> (iron and aluminum) .....	.28	.10	9,000
Mn (manganese) .....	.14	.05	9,000
Ca (calcium) .....	47.11	15.98	2,000
Mg (magnesium) .....	5.14	1.74	2,000
K (potassium) .....	1.93	.65	4,000
Na (sodium) .....	5.98	2.03	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.111	.04	500
Total .....	294.8740	100	
Total solids .....	210		100
Albuminoid ammonia .....	.070		500
Oxygen required .....	.40		200

<sup>a</sup>Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.330	0.11
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	3.68	1.25
NaCl (sodium chloride) .....	2.24	.76
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	13.93	4.72
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	1.82	.61
NaNO <sub>2</sub> (sodium nitrite) .....	.0045	
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	.33	.11
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	30.95	10.49
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	190.62	64.61
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.40	.14
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.19	.06
CaSiO <sub>3</sub> (calcium silicate) .....	.12	.04
SiO <sub>2</sub> (silica) .....	50.45	17.10
Total .....	295.0645	100

<sup>a</sup>Small amount.



No. 40.—*W. J. Little spring.*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on December 31, 1900, was 48.9° C., and on January 8, 1901, was 48.9° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.18; oxygen, 2.98; carbon dioxide (free), 14.20; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.02; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	45.73	16.52	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	7.76	2.80	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	163.50	59.06	100
NO <sub>3</sub> (nitric acid radicle) .....	Trace.	.....	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0010	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.67	.96	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe } (iron and aluminum) .....	.19	.07	9,000
Al }			
Mn (manganese) .....	Trace.	.....	9,000
Ca (calcium) .....	45.43	16.41	2,000
Mg (magnesium) .....	4.96	1.79	2,000
K (potassium) .....	1.59	.57	4,000
Na (sodium) .....	5.00	1.81	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.008	.....	500
Total .....	276.8390	100	500
Total solids .....	195.00	.....	100
Albuminoid ammonia .....	.004	.....	500
Oxygen required .....	.60	.....	200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.024	0.01
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.03	1.09
NaCl (sodium chloride) .....	2.00	.72
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	11.48	4.14
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	Trace.	.....
NaNO <sub>2</sub> (sodium nitrite) .....	.0015	.....
Na (HCO <sub>3</sub> ) (sodium bicarbonate) .....	1.79	.65
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	29.86	10.78
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	182.32	65.80
Mn (HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	.....
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.27	.10
Al <sub>2</sub> O <sub>3</sub> }		
CaSiO <sub>3</sub> (calcium silicate) .....	1.19	.43
SiO <sub>2</sub> (silica) .....	45.11	16.28
Total .....	277.0755	100

<sup>a</sup> Small amount.

No. 41.—*Mud spring.*

[Situated at base of Hot Springs Mountain, under free bath house. Sample for mineral analysis taken May 19, 1901. Temperature on December 29, 1900, was 46.8° C., and on January 8, 1901, was 48.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.14; oxygen, 3.44; carbon dioxide (free), 10.84; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.02; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	52.30	17.60	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	11.95	4.02	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	168.10	56.58	100
NO <sub>3</sub> (nitric acid radicle) .....	.44	.15	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0016		100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.		3,000
Cl (chlorine) .....	3.17	1.07	600
Br (bromine) .....	Trace.		5,400
I (iodine) .....	Trace.		5,400
Fe <sup>1</sup> Al <sup>1</sup> (iron and aluminum) .....	.29	.10	9,000
Mn (manganese) .....	Trace.		9,000
Ca (calcium) .....	46.89	15.78	2,000
Mg (magnesium) .....	5.22	1.76	2,000
K (potassium) .....	2.23	.75	4,000
Na (sodium) .....	6.49	2.18	4,000
Li (lithium) .....	Trace.		4,000
NH <sub>4</sub> (ammonium) .....	.018	.01	500
Total .....	297.0996	100	
Total solids .....	216.00		100
Albuminoid ammonia .....	.011		500
Oxygen required .....	.40		200

<sup>a</sup>Small amount.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.053	0.02
LiCl (lithium chloride) .....	Trace.	
KCl (potassium chloride) .....	4.25	1.43
NaCl (sodium chloride) .....	1.83	.62
KBr (potassium bromide) .....	Trace.	
KI (potassium iodide) .....	Trace.	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	17.30	5.81
MgSO <sub>4</sub> (magnesium sulphate) .....	.33	.11
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	
NaNO <sub>3</sub> (sodium nitrate) .....	.60	.20
NaNO <sub>2</sub> (sodium nitrite) .....	.0024	
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	31.00	10.43
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	188.89	63.53
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.42	.14
Al <sub>2</sub> O <sub>3</sub> }		
CaSiO <sub>3</sub> (calcium silicate) .....	.73	.25
SiO <sub>2</sub> (silica) .....	51.92	17.46
Total .....	297.3254	100

<sup>a</sup>Small amount.

No. 42.—*Magnesia spring.*

[Situated at base of Hot Springs Mountain, under Magnesia bath house. Sample for mineral analysis taken May 19, 1901. Temperature on January 8, 1901, was 58.3° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.05; oxygen, 2.23; carbon dioxide (free), 13.64; carbon dioxide (set free from bicarbonates on evaporating to dryness), 30.58; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	49.63	17.34	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.40	2.94	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	58.19	100
NO <sub>3</sub> (nitric acid radicle) .....	.44	.15	100
NO <sub>2</sub> (nitrous acid radicle) .....	.0008	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.83	.99	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe } (iron and aluminum) .....	.33	.11	9,000
Al }			
Mn (manganese) .....	.07	.02	9,000
Ca (calcium) .....	45.93	16.06	2,000
Mg (magnesium) .....	5.19	1.81	2,000
K (potassium) .....	1.72	.60	4,000
Na (sodium) .....	5.08	1.77	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.058	.02	500
Total .....	286.1788	100	.....
Total solids .....	203	.....	100
Albuminoid ammonia .....	None.	.....	500
Oxygen required .....	( <sup>b</sup> )	.....	200

<sup>a</sup> Small amount.

<sup>b</sup> Not determined.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.172	0.06
LiCl (Lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	3.28	1.14
NaCl (sodium chloride) .....	1.91	.67
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.43	4.34
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>a</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	.60	.21
NaNO <sub>2</sub> (sodium nitrite) .....	.0012	.....
NaHCO <sub>3</sub> (sodium bicarbonate) .....	.50	.17
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	31.24	10.91
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	186.02	64.96
Fe <sub>2</sub> O <sub>3</sub> } (ferric oxide and alumina) .....	.48	.17
Al <sub>2</sub> O <sub>3</sub> }		
Mn <sub>2</sub> O <sub>4</sub> (mangano-manganic oxide) .....	.10	.04
SiO <sub>2</sub> (silica) .....	49.63	17.33
Total .....	286.3632	100

<sup>a</sup> Small amount.



No. 43.—*Reservoir spring.*

[Situated at base of Hot Springs Mountain, in back yard of superintendent's office. Sample for mineral analysis taken May 19, 1901. Temperature on January 3, 1901, was 46.3° C., and on January 8, 1901, was 46.1° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 9.14; oxygen, 3.94; carbon dioxide (free), 8.59; carbon dioxide (set free from bicarbonates on evaporating to dryness), 28.92; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica).....	43.21	13.95	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	28.67	9.24	4,000
HCO <sub>2</sub> (bicarbonic acid radicle).....	160.50	51.78	100
NO <sub>3</sub> (nitric acid radicle).....	.22	.07	100
NO <sub>2</sub> (nitrous acid radicle).....	.0013		100
PO <sub>4</sub> (phosphoric acid radicle).....	.53	.17	2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	5.83	1.88	600
Br (bromine).....	Trace.		5,400
I (iodine).....	Trace.		5,400
Fe } (iron and aluminum).....	.44	.14	9,000
Al }			
Mn (manganese).....	None.		9,000
Ca (calcium).....	49.22	15.87	2,000
Mg (magnesium).....	4.24	1.37	2,000
K (potassium).....	8.84	2.85	4,000
Na (sodium).....	8.33	2.68	4,000
Li (lithium).....	Trace.		4,000
NH <sub>4</sub> (ammonium).....	.008		500
Total.....	310.0393	100	-----
Total solids.....	254		100
Albuminoid ammonia.....	.015		500
Oxygen required.....	1		200

<sup>a</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.023	0.01
LiCl (lithium chloride).....	Trace.	
KCl (potassium chloride).....	12.26	3.95
KBr (potassium bromide).....	Trace.	
KI (potassium iodide).....	Trace.	
K <sub>2</sub> SO <sub>4</sub> (potassium sulphate).....	5.37	1.73
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	25.44	8.20
MgSO <sub>4</sub> (magnesium sulphate).....	10.67	3.44
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>a</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	.86	.28
NaNO <sub>3</sub> (sodium nitrate).....	.30	.10
NaNO <sub>2</sub> (sodium nitrite).....	.0020	
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	12.58	4.06
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	198.00	63.86
Fe(HCO <sub>3</sub> ) <sub>2</sub> (ferrous bicarbonate).....	1.39	.44
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	None.	
SiO <sub>2</sub> (silica).....	43.21	13.93
Total.....	310.1050	100.00

<sup>a</sup> Small amount.

No. 44.—*Liver spring (cold).*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on January 4, 1901, was 8° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).— Nitrogen, 14.36; oxygen, 6.24; carbon dioxide (free), 21.83; carbon dioxide (set free from bicarbonates on evaporating to dryness), 2.24; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	12.50	34.29	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	2.50	6.86	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	12.10	33.19	100
NO <sub>3</sub> (nitric acid radicle) .....	.89	2.44	100
NO <sub>2</sub> (nitrous acid radicle) .....	Trace.	.....	100
PO <sub>4</sub> (phosphoric acid radicle) .....	Trace.	.....	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>a</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	1.83	5.02	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	( <sup>b</sup> )	.....	5,400
Fe <sub>2</sub> Al <sub>3</sub> (iron and aluminum) .....	.34	.93	9,000
Mn (manganese) .....	Trace.	.....	9,000
Ca (calcium) .....	1.89	5.18	2,000
Mg (magnesium) .....	1.36	3.73	2,000
K (potassium) .....	.94	2.58	4,000
Na (sodium) .....	2.10	5.76	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	.009	.02	500
Total .....	36.459	100	.....
Total solids .....	42	.....	200
Albuminoid ammonia .....	.010	.....	500
Oxygen required .....	.50	.....	200

<sup>a</sup> Small amount.

<sup>b</sup> Heavy trace.

HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	0.027	0.07
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	1.79	4.88
NaCl (sodium chloride) .....	1.58	4.31
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	( <sup>a</sup> )	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	3.55	9.69
MgSO <sub>4</sub> (magnesium sulphate) .....	.13	.36
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>b</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	Trace.	.....
NaNO <sub>3</sub> (sodium nitrate) .....	1.22	3.33
NaNO <sub>2</sub> (sodium nitrite) .....	Trace.	.....
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	8	21.83
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	7.21	19.68
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	Trace.	.....
Fe <sub>2</sub> O <sub>3</sub> Al <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina) .....	.49	1.34
CaSiO <sub>3</sub> (calcium silicate) .....	.32	.87
SiO <sub>2</sub> (silica) .....	12.33	33.64
Total .....	36.647	100

<sup>a</sup> Heavy trace.

<sup>b</sup> Small amount.

No. 45.—*Kidney spring (cold).*

[Situated on side of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on January 5, 1901, was 13° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, 15.30; oxygen, 5.29; carbon dioxide (free), 28.55; carbon dioxide (set free from bicarbonates on evaporating to dryness), 2.24; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			c. c.
SiO <sub>2</sub> (silica).....	15.06	34.40	8,000
SO <sub>4</sub> (sulphuric acid radicle).....	2.29	5.23	4,000
HCO <sub>3</sub> (bicarbonic acid radicle).....	15.14	34.58	100
NO <sub>3</sub> (nitric acid radicle).....	.44	1	100
NO <sub>2</sub> (nitrous acid radicle).....	.0007		100
PO <sub>4</sub> (phosphoric acid radicle).....	Trace.		2,000
BO <sub>2</sub> (metaboric acid radicle).....	( <sup>a</sup> )		3,000
AsO <sub>4</sub> (arsenic acid radicle).....	None.		3,000
Cl (chlorine).....	2.00	4.57	600
Br (bromine).....	Trace.		5,400
I (iodine).....	( <sup>b</sup> )		5,400
Fe <sup>1</sup> (iron and aluminum).....	.34	.78	9,000
Mn (manganese).....	Trace.		9,000
Ca (calcium).....	3.79	8.66	2,000
Mg (magnesium).....	1.45	3.31	2,000
K (potassium).....	1.02	2.33	4,000
Na (sodium).....	2.23	5.09	4,000
Li (lithium).....	Trace.		4,000
NH <sub>4</sub> (ammonium).....	.021	.05	500
Total.....	43.7817	100	
Total solids.....	41		200
Albuminoid ammonia.....	.016		500
Oxygen required.....	.80		200

<sup>a</sup> Small amount.<sup>b</sup> Heavy trace.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride).....	0.062	0.14
LiCl (lithium chloride).....	Trace.	
KCl (potassium chloride).....	1.94	4.36
NaCl (sodium chloride).....	1.72	3.86
KBr (potassium bromide).....	Trace.	
KI (potassium iodide).....	( <sup>a</sup> )	
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate).....	3.39	7.61
NaBO <sub>2</sub> (sodium metaborate).....	( <sup>b</sup> )	
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate).....	Trace.	
NaNO <sub>3</sub> (sodium nitrate).....	.60	1.35
NaNO <sub>2</sub> (sodium nitrite).....	.0011	
Na(HCO <sub>3</sub> ) (sodium bicarbonate).....	1.05	2.36
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate).....	8.73	19.61
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate).....	9.43	21.18
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate).....	Trace.	
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina).....	.49	1.10
Al <sub>2</sub> O <sub>3</sub> .....		
CaSiO <sub>3</sub> (calcium silicate).....	4.25	9.55
SiO <sub>2</sub> (silica).....	12.86	28.88
Total.....	44.5231	100

<sup>a</sup> Heavy trace.<sup>b</sup> Small amount.



No. 46.—*Fordyce spring.*

[Situated at base of Hot Springs Mountain. Sample for mineral analysis taken May 19, 1901. Temperature on January 6, 1901, was 51.5° C., and on January 8, 1901, was 51.5° C.]

*Gases* (number of cubic centimeters per liter at 0° C. and 760 mm. pressure).—Nitrogen, not determined; oxygen, not determined; carbon dioxide (free), not determined; carbon dioxide (set free from bicarbonates on evaporating to dryness), not determined; hydrogen sulphide, none.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.	Amount of water used for each determination.
			<i>c. c.</i>
SiO <sub>2</sub> (silica) .....	49.16	17.26	8,000
SO <sub>4</sub> (sulphuric acid radicle) .....	8.21	2.88	4,000
HCO <sub>3</sub> (bicarbonic acid radicle) .....	166.50	58.47	100
NO <sub>3</sub> (nitric acid radicle) .....	( <sup>a</sup> )	.....	.....
NO <sub>2</sub> (nitrous acid radicle) .....	( <sup>a</sup> )	.....	.....
PO <sub>4</sub> (phosphoric acid radicle) .....	.33	.12	2,000
BO <sub>2</sub> (metaboric acid radicle) .....	( <sup>b</sup> )	.....	3,000
AsO <sub>4</sub> (arsenic acid radicle) .....	None.	.....	3,000
Cl (chlorine) .....	2.50	.88	600
Br (bromine) .....	Trace.	.....	5,400
I (iodine) .....	Trace.	.....	5,400
Fe <sup>1</sup> (iron and aluminum) .....	.18	.06	9,000
Al <sup>1</sup> .....			
Mn (manganese) .....	.21	.07	9,000
Ca (calcium) .....	45.79	16.08	2,000
Mg (magnesium) .....	5.06	1.78	2,000
K (potassium) .....	1.57	.55	4,000
Na (sodium) .....	5.26	1.85	4,000
Li (lithium) .....	Trace.	.....	4,000
NH <sub>4</sub> (ammonium) .....	( <sup>a</sup> )	.....	.....
Total .....	284.77	100	.....
Total solids .....	200	.....	100
Albuminoid ammonia .....	( <sup>a</sup> )	.....	.....
Oxygen required .....	( <sup>a</sup> )	.....	.....

<sup>a</sup> Not determined.<sup>b</sup> Small amount.

## HYPOTHETICAL FORM OF COMBINATION.

Formula and name.	Parts per million.	Per cent of total inorganic material in solution.
NH <sub>4</sub> Cl (ammonium chloride) .....	( <sup>a</sup> )	.....
LiCl (lithium chloride) .....	Trace.	.....
KCl (potassium chloride) .....	2.99	1.05
NaCl (sodium chloride) .....	1.78	.68
KBr (potassium bromide) .....	Trace.	.....
KI (potassium iodide) .....	Trace.	.....
Na <sub>2</sub> SO <sub>4</sub> (sodium sulphate) .....	12.15	4.22
NaBO <sub>2</sub> (sodium metaborate) .....	( <sup>b</sup> )	.....
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (calcium phosphate) .....	.54	.19
NaNO <sub>3</sub> (sodium nitrate) .....	( <sup>a</sup> )	.....
NaNO <sub>2</sub> (sodium nitrite) .....	( <sup>a</sup> )	.....
Na(HCO <sub>3</sub> ) (sodium bicarbonate) .....	2.26	.79
Mg(HCO <sub>3</sub> ) <sub>2</sub> (magnesium bicarbonate) .....	30.46	10.70
Ca(HCO <sub>3</sub> ) <sub>2</sub> (calcium bicarbonate) .....	184.60	64.81
Mn(HCO <sub>3</sub> ) <sub>2</sub> (manganous bicarbonate) .....	.68	.24
Fe <sub>2</sub> O <sub>3</sub> (ferric oxide and alumina) .....	.27	.10
Al <sub>2</sub> O <sub>3</sub> .....		
SiO <sub>2</sub> (silica) .....	49.16	17.27
Total .....	284.89	100

<sup>a</sup> Not determined.<sup>b</sup> Small amount.

## SUMMARY OF THE RESULTS OF ANALYSIS.

On looking over the results of analysis of the various hot springs it will be seen that the total mineral matter in solution is very nearly the same in all except springs 12, 20, 27, and 43. Spring 12 is nearly cold, and contains only 170.1 parts of mineral matter per million; spring 20 contains only 231 parts of mineral matter per million; spring 27 only 258.7 parts of mineral matter per million, while spring 43 contains the relatively large amount of 310 parts of mineral matter per million. The average amount in all the springs is between 275 and 280 parts per million; seldom falling below 270 parts per million or going above 290 parts per million.

As to the percentage composition of the mineral matter in each hot spring the results are very much the same, except in springs 12, 27, 37, 41, and 43. Spring 12 has a higher percentage of silica and sulphuric acid than the average, and a lower percentage of bicarbonic acid and calcium; spring 27, a higher percentage of silica and a lower percentage of bicarbonic acid and calcium; springs 37 and 41, a higher percentage of sulphuric acid; and spring 43 a lower percentage of silica, bicarbonic acid, and magnesium, and a much higher percentage of sulphuric acid, potassium, and sodium. Although the springs mentioned above vary to some extent from the other springs in the amount and composition of their mineral matter contained in solution, this variation is not enough, in the author's opinion, to make any difference in their medicinal value except in the cases of springs 12 and 43, the first of which is markedly weaker in medicinal constituents than the other springs, and the second of which has much more of those salts present which have a laxative effect.

From what has already been said, combined with the analyses of these waters, it will at once be seen why they have been used with such excellent results in the treatment of rheumatism, gout, syphilis, etc. We may sum up under four heads:

(1) The waters are hot, and consequently possess the medicinal value of all thermal waters, i. e., when used as a bath, in the ordinary manner followed in such cases, they stimulate the flow of sweat and urine, and thus give the system a thorough washing out each day. In this manner uric acid and syphilitic poisons are removed from the body. Mercury and other metallic poisons are also removed, in consequence of which much larger doses of mercury can be given to the patient than would otherwise be possible.

(2) These waters contain iodides and bromides,<sup>a</sup> which, although present only in traces, undoubtedly have a marked alterative effect on the system, and form soluble compounds with the salts of mercury, thus aiding in their elimination from the system.

(3) The presence of lithium in these waters, even though in traces, very likely accounts, to some extent, for the removal of some of the uric acid from the system, and the consequent improvement in the condition of rheumatic and gouty persons.

(4) All of these springs contain quite large amounts of calcium and magnesium bicarbonates. The calcium and magnesium salts of uric acid are much more soluble than the uric acid itself. Taking these two facts into consideration, it seems plausible to assume that a great deal of the curative effects of these waters is due to the formation of the more soluble compounds, calcium and magnesium urate, which can more easily be eliminated from the system than the uric acid itself.

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<sup>a</sup> See Mineral Waters of the United States, by J. K. Crook, p. 42.



# GEOLOGICAL SKETCH OF THE HOT SPRINGS DISTRICT, ARKANSAS.

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By **WALTER HARVEY WEED**,  
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## GEOGRAPHICAL LOCATION.

The Hot Springs of Arkansas are situated in the geographical center of the State, 50 miles distant from Little Rock, and about 75 miles east of the Indian Territory line. A city of about 60,000 inhabitants has been built up about the Hot Springs and the place is a resort for a large number of visitors from all parts of the Union. The locality is accessible by two railway lines which connect with the Iron Mountain Railway and the Choctaw route, running through cars from the large cities of the country. The location is 600 feet above sea level and lies at the easterly base of the mountain complex known as the "Ouchita Range," the nearby peaks of which are oftentimes called the "Ozark Range," although that name really applies to the mountains in the northern part of Arkansas and the southern part of Missouri.

## HISTORICAL NOTES.

The Arkansas Hot Springs have been known since the early settlement of Louisiana. Although it is only a legend that they were visited by De Soto on his trip to the Mississippi, there is no doubt that they were used by the Indians before the advent of Columbus, as abundant evidence was found in early days that the Indians quarried the dense rocks near the Hot Springs for arrowheads and spearheads and utilized the spring waters for bathing.

In 1804 two members of the Lewis and Clarke exploring expedition visited the place and found that white visitors had already used the waters for bathing. In 1818 the lands on which the springs are located were ceded to the General Government by the Quapaw Indians and became afterwards a part of the Territory of Arkansas. The ground about the springs was located by various claimants before the organization of the Territory of Arkansas, but by act of Congress the springs and the ground about them were reserved in 1834 for the United States Government, thus making the first national park reservation of the country. Owing to the claims made by various parties to a private ownership of the springs they remained in the possession of such claimants until the United States Supreme Court decided in favor of the Government in 1877.



The act of Congress of March 3, 1877, provided for the appointment by the President of three commissioners, whose duties are defined by said act as follows:

SEC. 3. That it shall be the duty of said commissioners, after examination of the topography of the reservation, to lay out into convenient squares, blocks, lots, avenues, streets, and alleys, the lines of which shall correspond with the existing boundary lines of occupants of said reservation as near as may be consistent with the interests of the United States, the following described lands, to wit: The south half of section twenty-eight, the south half of section twenty-nine, all of sections thirty-two and thirty-three, in township two south and range nineteen west; and the north half of section four, the north half of section five, in township three south and range nineteen west, situate in the county of Garland and State of Arkansas, and known as the Hot Springs Reservation.

SEC. 4. That before making any subdivision of said lands, as described in the preceding section, it shall be the duty of said board of commissioners, under the direction and subject to the approval of the Secretary of the Interior, to designate a tract of land included in one boundary, sufficient in extent to include, and which shall include, all the hot or warm springs situate on the lands aforesaid, to embrace, as near as may be, what is known as Hot Springs Mountain, and the same is hereby reserved from sale, and shall remain under the charge of a superintendent, to be appointed by the Secretary of the Interior: *Provided, however,* That nothing in this section shall prevent the Secretary of the Interior from fixing a special tax on water taken from said springs, sufficient to pay for the protection and necessary improvement of the same.

In the year mentioned a Commission was appointed and recommended a permanent plan of improvement. Under that plan the land not needed for permanent reservation was platted in streets and alleys, and lots were assigned to various individuals. The original reservation consisted of 2,529 acres, of which 700 acres were awarded to individuals for business and residence purposes, 358 acres were used for streets and alleys, and 570 acres were platted in town lots reserved for future disposal.

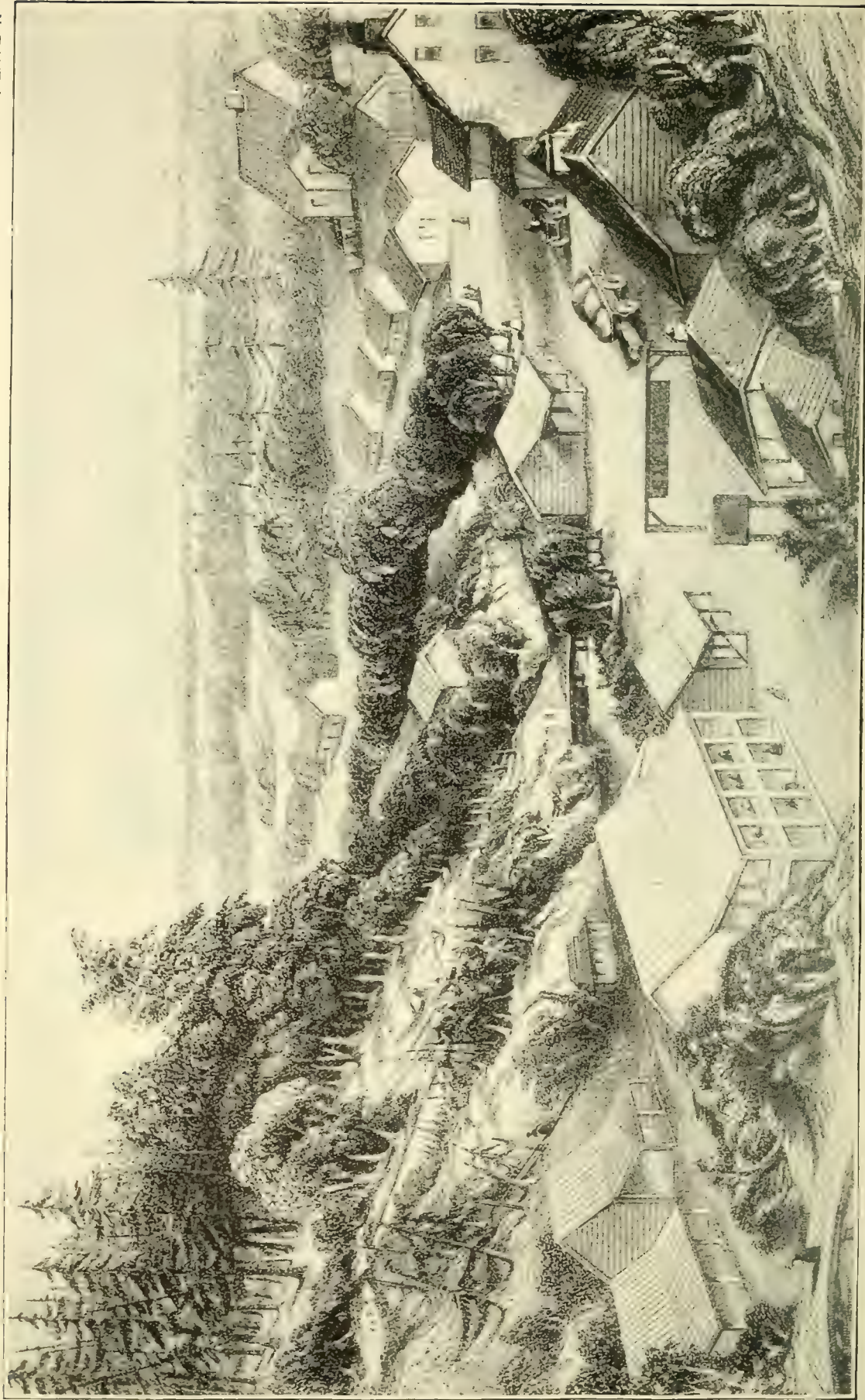
In 1876 the town of Hot Springs was incorporated, and in 1881 the General Government donated to the city the ground platted for streets and alleys. The Congressional enactment of June 16, 1880, provided as follows:

SEC. 3. That those divisions of the Hot Springs Reservation, known as the mountainous districts, not divided by streets on the maps made by the commissioners, but known and defined on the map and in the report of the commissioners as North Mountain, West Mountain, and Sugar Loaf Mountain, be, and the same are hereby, forever reserved from sale, and dedicated to public use as parks, to be known, with Hot Springs Mountain, as the permanent reservation.

Under these two acts the mountains adjacent to the springs are permanently reserved for parks, the hot waters are piped to various bath houses, and the supply is under the control of a superintendent of the Hot Springs Reservation, appointed by the Secretary of the Interior. The regulations now prescribed by that Department provide for a rental of land used by various individuals and for the payment of \$30 per year for each tub used by bathing establishments. The income is used for the payment of administrative expenses, for the maintenance of a free bath house, for the building of roads and pathways on the mountains back of the springs and the adjacent mountains, and for gardening. The receipts amount to about \$18,000 per year. The superintendent is charged, under the supervision of the Secretary of the Interior, with the care of the entire reservation as well as its protection and improvement. It is therefore policed and improved by the Department. The results achieved by this wise system speak for them-









selves; beautiful driveways, picturesque walks, and fine flower beds add their charm to the natural beauty of the place, and the present aspect bears but a slight resemblance to the scene shown in the accompanying illustration, Plate I, which represents the springs as they appeared in 1836.

#### RELATION OF HOT SPRINGS DISTRICT TO REST OF THE STATE.

Central Arkansas consists of a low-lying, nearly level eastern portion, and a western hilly or mountainous region. The first region extends from the Mississippi River westward to Little Rock, Benton, and Malvern. The hilly country of the Ouachita Mountain system begins just west of the Iron Mountain Railroad, where it has a width of 36 miles, and extends westward, gradually narrowing as it approaches the Indian Territory. The eastern level country is part of the Tertiary Mississippi Valley region. The western hilly country consists of a central complex of hills, flanked by sharp spurs and ridges, which extend outward into a much lower country of slight relief. This hilly country, is dignified by the name of the "Ouachita Mountain system," the ridges rising gradually in elevation westward. Near the Indian Territory line the general level of the intermontane plain is 1,000 feet above tide and the crests of some of the ridges attain elevations above 2,500 feet. Near Hot Springs the mountain area seldom attains an elevation of more than 1,200 feet above the sea, or 600 feet above the surrounding country, yet, when seen from the lower country about it, the hills rise so abruptly that they appear to deserve their designation. The mountains near the Hot Springs are particularly impressive, and the local summits have received special designations, as "West Mountain," "Indian Mountain," etc. These mountains have been grouped together by some writers under the name of the "Ozark system," but they have been more fittingly christened the "Zigzag" Range by Professor Branner, of the State geological survey. This range has an extreme length of 25 miles and a width of 6 to 8 miles. The general trend of the ridges is almost at right angles to the system. These ridges are narrow and sharp, with a height of 500 to 600 feet, and they are particularly numerous in the vicinity of the Hot Springs.

#### TOPOGRAPHY.

The Hot Springs are situated in a valley between two wooded, rocky ridges known as "West Mountain" and "Hot Springs Mountain." The water issues from vents in the old and gray hot-spring deposit, or tufa, that covers the basal slopes of Hot Springs Mountain east of Hot Springs Creek. This location is on the outer border of the mountain system. To the east the country falls away gently to the Ouachita River, and the city of Hot Springs has been built partly in the ravine and the intermontane basin to the north and partly in the eroded plateau lying south of the springs and outside of the mountain area. The mountain slopes are rocky, and are often ribbed with abrupt cliffs and rugged ledges with extensive slopes of talus. They are generally thickly mantled with a heavy forest growth of oak, pine, chestnut, and other common forest trees, and they support a more or less abundant undergrowth. The ravines are generally

narrow and the streams swift running, but good exposures of the underlying rocks are seldom seen, owing to the thick forest that covers the slopes. There is an evident relation between the hard rocks and the hills and between the softer rocks and the valleys, although the streams do not accord with any definite geological structure, but flow in synclines, in eroded anticlines, and across the strike of the beds as well. Several gaps indicate old and now abandoned stream courses and show a prolonged period of adjustment, in which the streams shifted several times before reaching their present position. Although the springs are on the borders of these mountains this location is not wholly outside of the mountain area, since the Trapp Mountain Range lies south of the Ouachita River, so that the springs are on the north side of a synclinal basin that forms an embayment between the main Ouachita system and a small east-and-west spur on the south. The region is well watered and well drained. In the immediate vicinity of Hot Springs the Hot Springs Creek and Gulpna Creek, both of which flow into the Ouachita River, drain the entire region, the former stream flowing due south and reaching the river 4 miles below the city.

The lower country near the springs, upon which a considerable part of the city is built, is a dissected plain in which broad plateau levels alternate with shallow drainage courses that are tributary to Hot Springs Creek.

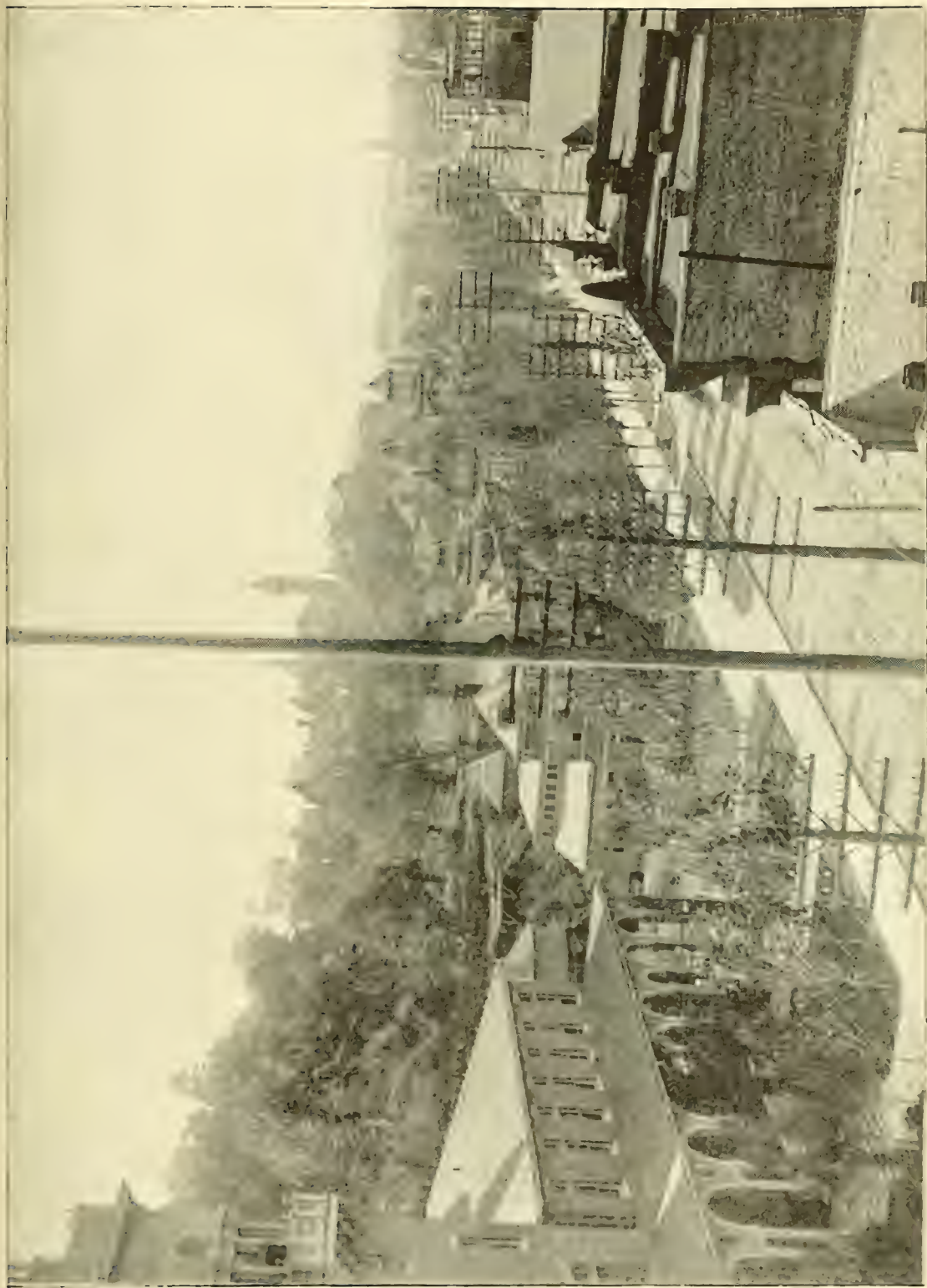
The climate of the region is a mild one, lacking both the extreme heat of summer and the cold of winter. In the summer months the air is tempered by the breezes from the mountains, and in winter the average temperature is very slightly below that which prevails at New Orleans and other Southern cities. Flowers and shrubs of semitropical character grow in the open air, but the occasional frosts of winter are so sharp that a strictly semitropical vegetation will not exist.

#### ROCKS OF THE DISTRICT.

The rocks seen about the Hot Springs are chiefly of sedimentary origin and were formed beneath the waters of a Paleozoic sea. They occur in well-defined formations, which were folded when the mountains of the region were formed by the compressive stresses of earth movements, and these folds have subsequently been eroded by ordinary atmospheric agencies. These rocks are cut by a few narrow, insignificant dikes of igneous rock, which are supposedly connected with the large masses of granite and other igneous rocks now seen at Magnet Cove and Potash Sulphur Springs. In addition to the rocks mentioned there is a considerable area of dark-gray and porous travertine, or calcareous tufa, formed by the Hot Springs.

The sedimentary rocks seen in the vicinity of the Hot Springs consist of shales, sandstones, a few beds of impure limestone, and the rock called novaculite. This last-named rock, of which the well-known Arkansas whetstones are made, is the most conspicuous and important rock in the locality. It is the typical rock of central Arkansas, and, though found over a large area, the material pure enough to be used for whetstones is confined to the vicinity of the Hot Springs. It is this rock that has, by reason of its hardness and its resistance to erosion, made the mountains about the springs, and it forms the cliffs and prominent ledges seen in the district. The bedded rocks form a series





VIEW OF CENTRAL AVENUE, LOOKING SOUTH.





shown in the following table, in which the youngest beds are placed at the top of the column and the oldest strata at the bottom.

Geological age.	Thickness of beds.	Character of rock.
	<i>Feet.</i>	
Carboniferous .....	200	Shales; gray or black graphitic shales with fragments of plant remains, red and yellow colored when altered.
	250	Sandstone, impure and clayey, with softer layers alternating with softer material.
Lower Silurian .....		Quartzose sandstones, passing at times into conglomerates and well exposed along the basal slopes of Hot Springs Mountain.
	12	Novaculite breccia.
	5	Impure novaculite, with iron and manganese.
	100	Novaculite in thick and thin beds, with some layers of siliceous shales.
	75	Sandstone passing into novaculite.
	38	Shale, siliceous, and passing into novaculite.
	200	Massive novaculite, from which whetstone is taken.
	230	Shale, siliceous, with thin layers of novaculite.
		Impure novaculite.
	200	Shales, red and green and gray, with siliceous layers.
		Shales, black, and carrying fossil remains (graptolites).
	200	Limestone, thinly bedded, blue, and generally argillaceous.
		Sandstones.

*The rock structure.*—Near the Hot Springs these rocks have been compressed into great folds which now form the mountains, and this compression is so great that the folds have been pushed over, or overturned, and in the gorge of Hot Springs Creek the section now exposed shows the younger beds resting beneath the older ones. In addition to this there has been some faulting in Indian Mountain, by which an overthrust has pushed up the older beds over younger ones. For this reason the section, as given above, is not always easily made out, but it can be seen in the slopes of West Mountain, although, as will be noted there, the younger beds lie below the older and the rocks have a dip of from  $25^{\circ}$  to  $70^{\circ}$ . The Carboniferous shales, which are the youngest rocks of the district, are well exposed on Malvern avenue near the Park Hotel, where the olive-colored, sandy shales have been found to contain plant stems and fragments of fern fronds. The shales are rarely indurated enough to form slates, though a few quarries have been opened in them and slate of a poor quality extracted. Where the shales are slightly altered they are sometimes valuable for brick and terra-cotta burning, though most of the clay used for that purpose is derived from the disintegrated material washed into the creek bottoms.

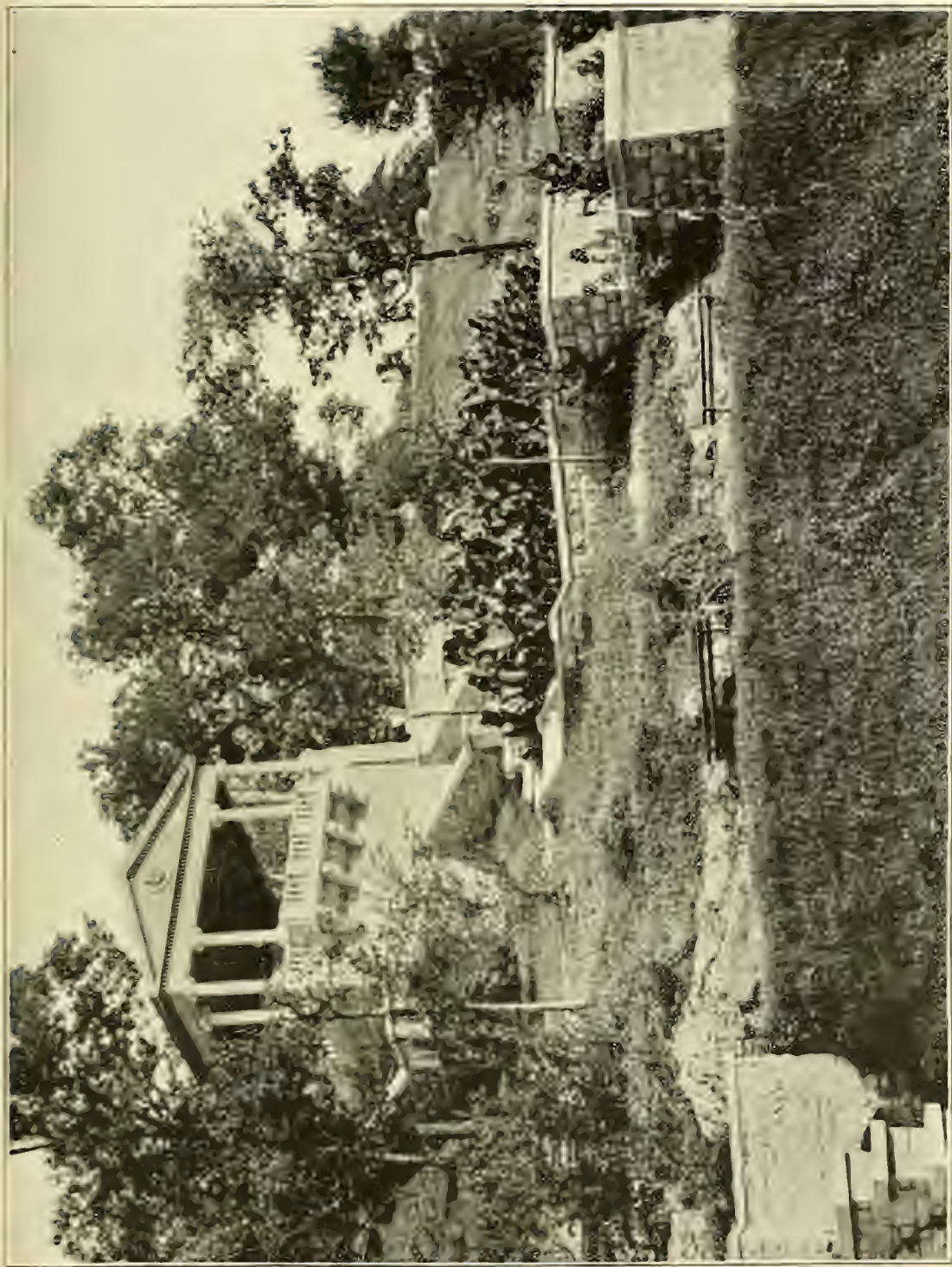
The sandstones are of variable texture and composition. The coarser-grained rocks are nearly pure quartzose sand, but the intermediate beds are quite clayey. The chief sandstone horizon seen at the springs is the one lying just above the novaculites, and this rock is the one which is so prominent on Hot Springs Mountain and West Mountain.

The novaculites are the most interesting rocks of the region. They consist of nearly pure silica, containing less than one-half of 1 per cent of other material. The rock is very dense, homogeneous, of a cream or white color, and fine grained, resembling in appearance the finest Carrara marble. These rocks are used for whetstones, the finer-grained form being called Arkansas stone and the coarser-grained rock the Ouachita stone. This material has a marked conchoidal fracture

and resembles chert in its general appearance, although, as will be shown later, this appearance is purely a superficial one and the material differs markedly from chert in its origin and composition. Although brittle and lacking the toughness of chert, it was extensively used by the Indians, who quarried it by building fires upon the outcrops until the stones were heated and then quenching the fire with water, thus chilling the rock and causing it to split and spall into fragments which were easily removed. In this condition it was readily chipped by the use of round stone hammers, great quantities of which have been found by the early settlers and which the writer has seen at some of the more remote quarries. The rock is finely jointed, and in quarry faces this jointing is more conspicuous than the bedding planes. These phenomena may be well observed in almost any of the excavations seen along the main street above the Government reservation. The finer-grained material seldom forms good outcrops, because of this jointing and also because the rock contains a small amount of water, which, when frozen during the frosts of winter, shatters the stone and covers the outcrop with fine *débris*. This *débris* is extensively used as a road material, and wherever applied forms a most excellent surface.

The novaculite formation is from 500 to 600 feet in thickness, which includes some flinty shales, some soft shales, and some sandstones. The novaculites proper are prominent members of this formation and occur in beds a few inches to 12 or 15 feet thick. When these beds are less than 4 inches thick the rocks lose the novaculite character, and are more like flinty shales. When examined under the microscope the rock is found to present a very uniform appearance, and to consist of extremely minute interlocking grains of cryptocrystalline silica. Chemical tests show that this silica is quartz and not amorphous silica. Thin sections also disclose the presence of numerous cavities in the rock quarried for whetstones. These cavities have been found to present a rhomboidal outline, and they correspond in form and position to included patches of calcite found in the same rock where the bed passes beneath the creek levels. It has been assumed that these cavities are formed by the dissolution and removal of the calcite, and as the material from beneath the water level is of slight value as a whetstone, it has been reasoned that the abrasive qualities of the Arkansas stone are due to the presence of these calcite cavities. The origin of the rock has been the subject of considerable speculation from the earliest times to the present. It has been commonly asserted that it is a very fine-grained sandstone, which has been indurated and altered by hot-spring action. This explanation is not adequate, however, since the same beds are exposed on the flanks of the Ouachita Mountain system for a total length of several hundred miles. Moreover, the character of the grains does not permit of the assumption that they were originally rounded and that the spaces between have been filled by secondary deposition of silica, as is commonly the case with many quartzites. The writer's belief is that the evidence supports the opinion that the rocks were formed as a chemical precipitate in the deep seas of a Silurian ocean, and that comparatively little alteration beyond induration has taken place. Such a theory seems to accord very well with the chemical and physical nature of the rock and with the facts now known in regard to the origin of some of the early geological sediments.



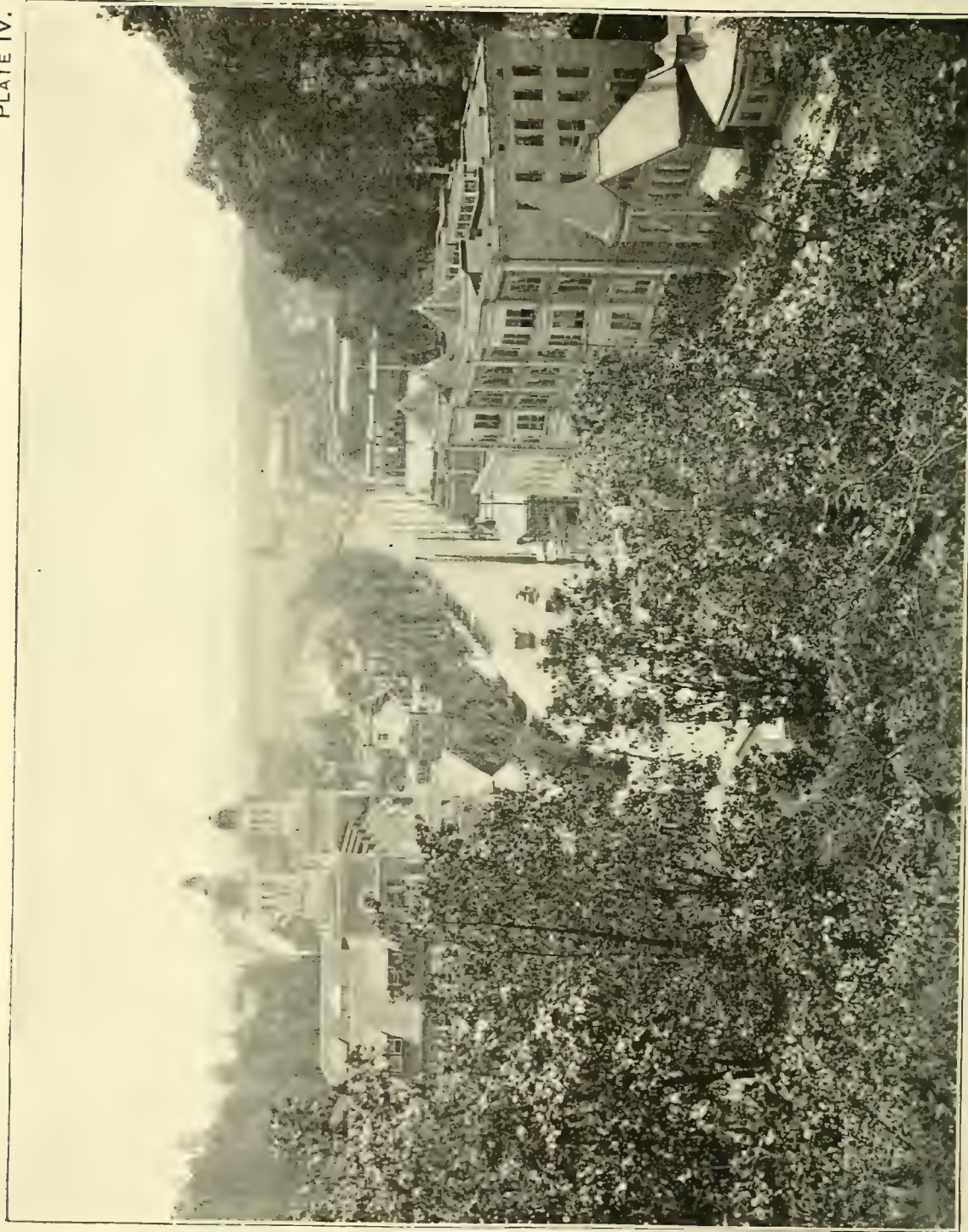


PAVILION AT MAIN ENTRANCE TO HOT SPRINGS RESERVATION.









HOT SPRINGS. CENTRAL AVENUE, LOOKING SOUTH, SHOWING ARLINGTON HOTEL AND BATH-HOUSE ROW ON HOT SPRINGS RECREATION CATERING

## IGNEOUS ROCKS.

Besides the sedimentary rocks just noted there are four narrow dikes of igneous rock about one-half mile south of the mountain borders and near the city limits. These rocks are dark-colored mica traps, a form of rock called "ouchatite." They are chiefly interesting because they show that there was some deep-seated body of molten material from which the dike fissures were supplied. Small dikes are found north of the city, east of the city, and in considerable abundance about Potash Sulphur Springs and at Magnet Cove. These dikes have a generally ESE.-WNW. direction, showing that the fissures are parallel to the mountain sides. They are from 1 to 4 feet wide and are generally much altered, so that the outcrop is inconspicuous, or is covered by vegetation, and when the rock is broken black mica in small flakes is the only mineral seen.

## FOSSILS.

The age of the sedimentary rocks is determined by the fossil remains found in them. The black shales which underlie the novaculites contain remains of a curious hydrozoa. These fossil remains are known as *graptolites*, and the forms identified at the Hot Springs belong to the upper part of the Lower Silurian age (Trenton and Utica). New types of these fossils peculiar to the Hot Springs are illustrated in the Novaculite report issued by the Arkansas geological survey. Besides these curious forms, a few shell remains (*brachiopods* and *lamellibranchs*), corals, and worm trails have been found. The *graptolites* occur on the north side of the hill on a small stream drainage on the west side of the continuation of Park avenue. They are also seen in a very black shale forming the bluff on the west side of Park avenue above the Hotel Hay and below the Barnes House. Similar fossils also occur on Whittington avenue, one-fourth of a mile above the head of Central avenue, at a point where the creek crosses the street.

Plant remains of Lower Carboniferous age have been found in the shales exposed in the excavation for a cellar on the western side of Malvern avenue, 100 feet north of the Park Hotel. The shales are varicolored, brown, red, gray, and black, but the fossils occur in the olive-colored, sandy shales. Similar fossils were also found in Ouachita avenue at the Hot Springs.

## OCCURRENCE OF THE HOT SPRINGS.

The hot waters issue from the base and lower portion of the slopes east of the valley. This area is a narrow strip, a few hundred feet wide, and a quarter of a mile long. In its general aspect this area is distinguished from the rest of the mountain by its patches of barren gray tufa, the old hot-spring deposit, and the absence of forest growth. From the descriptions given by earlier writers, it is evident that this difference in appearance and vegetation was formerly very marked. To-day the springs are all covered, and mostly concealed beneath turf and shrubbery. The old tufa deposit is in large part covered by soil and plants. The creek is arched over and sidewalks and roadways are built on it. The space between creek and hillside is covered by the bathing establishments, which, in many instances, are built directly over large springs.



The landscape gardener has modified the old slopes, filled up the gullies, and built roads and footpaths, until the hot-spring area is a beautiful park and a fitting setting for the springs.

The great contrast between the present appearance of this area and that of a half century ago is shown by a comparison of the sketch made by Prof. David D. Owen, State geologist, in 1859, which is reproduced in Plate I, and the present aspect, shown in Plate II and the frontispiece.

The diagram accompanying this report, Plate IX, shows the location of the hot springs with reference to the buildings on the reservation. The numbers on this map correspond to those given in the table of analyses. Professor Owen's sketch map is also reproduced for comparison.

The topography of the district is shown in Plate X, which is part of a general sheet prepared by the United States Geological Survey. This shows that the springs occur at the southwest end or "nose" of Hot Springs Mountain. There is nothing unusual or remarkable in this topographic position, for it accords with that of many other springs of the region—as, for example, Bonanza Springs and Big Chalybeate of the plate.

It is difficult for the average visitor of to-day to form an idea of the natural appearance of the springs. The larger springs formerly issued abruptly from the tufa slopes and did not possess the bowls and basins seen at the Mammoth Hot Springs of the Yellowstone. An artificial cutting made into the mound of the Cave spring (Plate V) shows a section of the hot-spring deposit, and if the door be opened the waters will be seen flowing into the basin cut to collect them, and depositing creamy alabaster-like tufa, and the brilliant emerald-green tufa, whose color is due to the growth of hot-water algæ. Many of the smaller springs are mere oozes, with no well-defined channel. A considerable number of these are gathered into one reservoir at the base of the tufa bluff between the Arlington Hotel and the Superior Bath House. Another spring is seen near the Hale Bath House, where it issues from a cavity in the tufa and flows into the basin seen in Plate VI. There is a constant flow from the tufa wall back of this masonry platform, forming the dripping spring, where thousands of visitors daily drink hot water direct from the rock. At this place also the green algaous growth may be seen. Owing to artificial protection given the springs, but few notes could be taken of their present appearance, and these are recorded in the following table: <sup>(1)</sup>

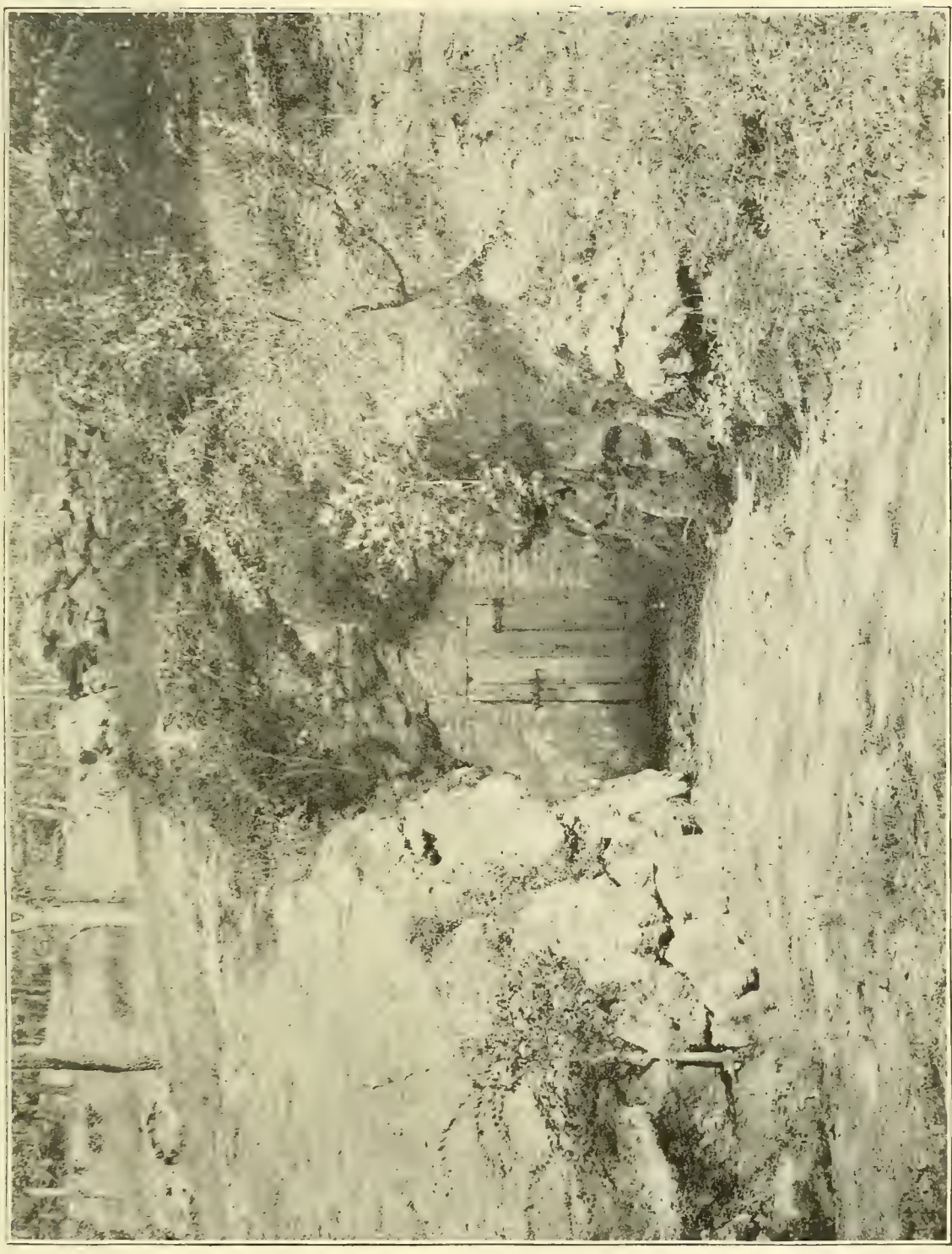
TABLE OF HOT SPRINGS.

1. *Egg spring*.—Arched over and covered by soil and grass. Water about 8 feet below surface of ground.
2. *Arsenic*.—Under cover of Arlington Hotel.
3. *Arlington spring*.—Spring issues from between rock ledges. Water level 7 feet below ground. Spring lies beneath gentle grassy slope.
4. *Cliff spring*.—Outflow from base of tufa cliff back of Arlington Hotel. Spring arched over and can not be seen.
5. *Avenue spring*.—This spring is covered by an arch that is above ground. Outflow resulted from excavations and spring is not on the old maps.
6. *Bath House spring*.—In rear of Arlington Bath House. Outflow arched over and runs into tank to south.

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<sup>(1)</sup> The numbers and some of the names of these springs were given by Mr. J. K. Haywood and Mr. Martin Eisele, superintendent of the reservation.



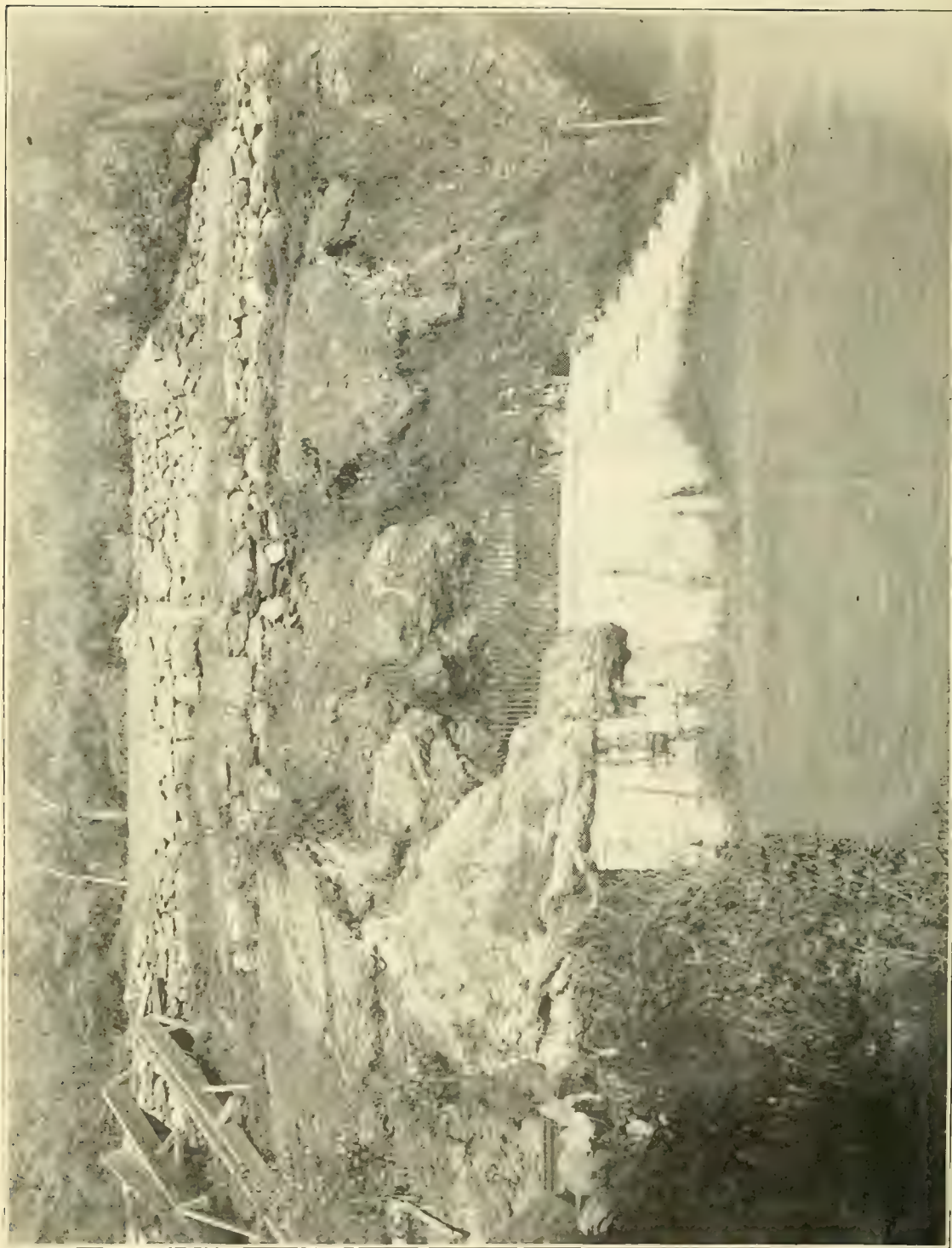


LOOKING EAST, SHOWING "CAVE SPRING."  
Taken at head of steps on Arlington Supply Road.









DRIPPING SPRING, LOOKING EAST, SHOWING TUFU BLUFF AND THE SECURED AND INCLOSED HALE SPRING BELOW.

7. *Imperial spring*.—This spring is the result of sinking a hole to develop hot water in 1892. It lies beneath the lawn near No. 5.
8. *Crystal spring*.—This spring is now nearly dead. It is covered by a rustic stone arch open on the west.
9. *Rector spring*.—Outflow from base of tufa cliffs south of Arlington Hotel. Is now covered by long arch and tank.
10. *Cave spring*.—The mound about this spring has been dissected by an open cut 5 feet wide extending from the border to the center. The spring is inclosed in masonry and closed by a door. The best example of recent tufa formation is seen here.
11. *Little Iron*.—Is one of a cluster of three or more seepages and outflows gathered into the long narrow reservoir built against the base of the tufa bluff south of and adjacent to the Arlington Hotel.
12. *Little Geyser*.—A very small spring, arched over and lying 12 feet beneath the roadway.
13. *Little Iron south*.—An undercliff seepage collected in same reservoir as No. 11.
14. *Ral spring*.—Formerly a big spring flowing from a mound of tufa; but this, as well as No. 12, lost most of its outflow when spring No. 16 was deepened.
15. *Big Iron spring*.—Not visible. Comes from under bottom of tufa cliff 5 to 6 feet below the present surface of the ground.
16. *Imperial spring south*.—This was developed by digging in search of a new source of water.
17. *Arsenic spring north*.—Bricked up and not seen; lies at base of tufa cliff.
18. *Hitchcock spring*.—Water level 11 to 12 feet below surface of grassy flat south of Arlington Hotel. Inclosed in masonry, with wooden manhole.
19. *Sumpter spring*.—Completely inclosed and not visible.
20. *Superior spring north*.—Inclosed and not to be seen. Occurs beside sandstone outcrop.
21. *Abum spring*.—Ten feet beneath sidewalk, but accessible by stairway. Inclosed in partition.
22. *Superior spring south*.—Spring vaulted and covered by earth. Lies at end of sandstone reef.
23. *Twin spring north*.—Vaulted over and concealed beneath road; 6 feet down to water.
24. *Twin spring south*.—Vaulted over and concealed beneath road; 6 feet down to water.
25. *Old Hale spring*.—Under floor of Hale Bath House.
26. *Palace spring*.—Concealed. Lies at border of wagon road back of the Dripping spring.
27. *Tunnel spring*.—Arched over by white novaculite masonry structure.
28. *Maurice spring*.—Arched over by white novaculite masonry structure.
29. *Dripping spring*.—This is the only spring from which public can get water directly. It drops from freshly deposited tufa, colored green by hot-water algæ.
30. *Arch spring*.—Outflow escapes into the creek spring 14 feet beneath the lawn in front of the southwest corner of Hale Bath House.
31. *Haywood spring*.—Two small outflows covered up by one arch. They lie on the northeast side of the wagon road and on the east side of the rock gully.
32. *Noble spring*.—Covered by white novaculite building standing above ground.
33. *Lamar spring*.—Covered by white novaculite building standing above ground.
34. *Wiley spring*.—Covered by white novaculite building, but outflows really from beneath the wagon road.
35. *Harding spring*.—Seepages (yet to be developed) from base of retaining wall of road back of northeast corner of Palace Bath House.
36. *Eisele spring*.—This spring does not flow when water is pumped from the well on the military reservation.
37. *Stevens spring*.—This was developed in digging foundations for the retaining wall of the wagon road. The water is piped to a drinking fountain.
38. *Horseshoe spring*.—Flows from under floor of Horseshoe Bath House.
39. *Army and Navy spring*.—Now covered up by soil and turf.
40. *W. J. Little spring*.—Fine small seepage beneath road.
41. *Mud spring*.—Under coal bin of Free Bath House.
42. *Magnesia spring*.—Inaccessible; beneath bath house.
43. *Reservoir*.—Twenty feet beneath concrete paving back of superintendent's office.
44. *Liver spring*.—Cold-water spring.
45. *Kidney spring*.—Cold-water spring.
46. *Fordyce spring*.—Under Palace Bath House.
47. *New spring*.—Developed by sinking pipe in ground near No. 5.
48. *New spring*.—Developed by digging well near No. 2.



## HOT SPRING TUFA DEPOSIT.

As already noted, the hot-spring area is characterized by a deposit of calcareous tufa, or travertine, formed by the hot waters, and covering not only a large part of the mountain slope about the existing hot springs, but also extending westward to the Happy Hollow ravine and occurring far above any existing springs in the slope above the band stand (Plate III). Tufa deposits are common about both hot and cold water springs whose waters carry carbonate of lime in solution. This material is precipitated when the carbon dioxide of the waters escapes upon exposure of the water to the atmosphere. At the Arkansas Hot Springs a very small amount of carbonate of lime is held in the waters, yet it is sufficient to coat the hot-water pipes and to fill wooden troughs used to conduct the waters. In the Cave spring and at the Dripping spring (Plate VI) the tufa may be seen now forming. It is therefore not certain that the waters which formed the great tufa deposits of the place were any richer in lime carbonates than those of to-day. This tufa is seen in its natural state at many places about the springs, but is particularly well seen at the Cave spring back of the Arlington Hotel. It is of a gray color and porous texture on the surface, but when quarried is pure white, compact, and crystalline. The steps shown in Plate VII are cut in it and the porous texture is seen in the fragments on edge alongside.

This tufa consists almost wholly of carbonate of lime, carrying very small and varying amounts of manganese (oxide) and iron oxide. The manganese is frequently prominent as a black powder, or occurs in blackish layers through the rock. The analysis made for Owen in 1859 of the material deposited in the pipe accords so exactly with that of the deposit now forming that it is reproduced.

*Analysis of hot-spring tufa formed in pipes carrying hot water to bath houses.*

	Per cent.
Carbonate of lime .....	92.620
Sulphate of lime .....	.085
Carbonate of magnesia .....	3.060
Carbonate of iron .....	.210
Carbonate of manganese .....	.190
Potassa .....	.107
Silica .....	.119
Total .....	99.391

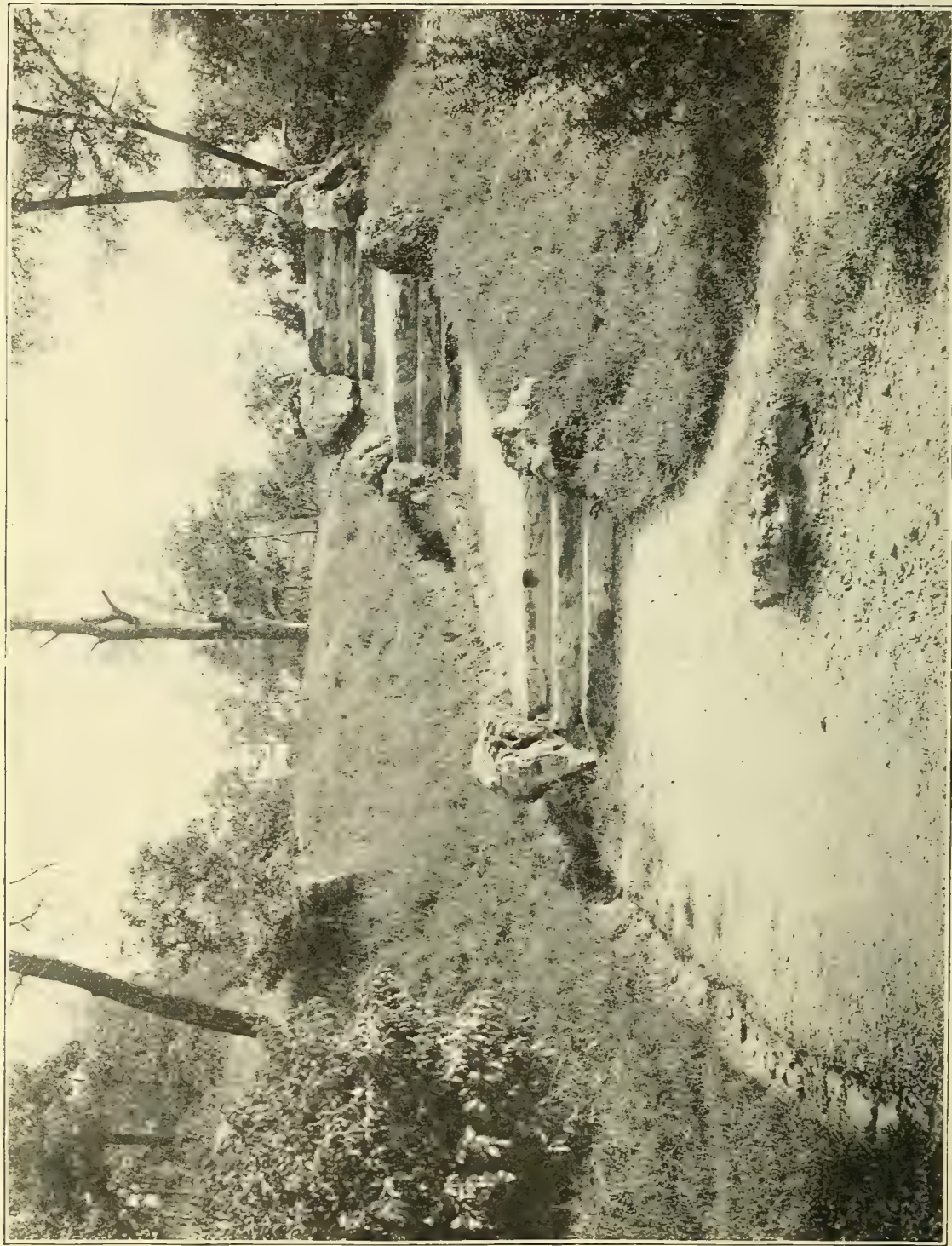
In the Cave spring the freshly deposited tufa is tinted orange by the algæ that live in hot water, and green by the species that flourish at slightly lower temperatures. These colors are purely vegetable and disappear if the deposit be heated.

This tufa deposit covers an area of approximately 20 acres, and varies from a few inches to 6 or 8 feet in thickness. Its occurrence shows that some of the springs formerly flowed to the west, and that the waters covered a larger area than at present.

The broad area covered by the tufa does not mean that the hot waters covered this entire area at any one time, for the algaous growth described as filling the hot-water streams causes a filling up of the channel and a diversion of the water to a different place. In two instances the waters built up mounds about the springs. The most noticeable of these is that of the Cave spring, which has been artifici-







STEPS AND WALK OF TUFA, ON RESERVE, NEAR ARLINGTON HOTEL AND CAVE SPRING.

ally breached in the development of a larger water supply from the spring. (Plate V.) Above the music pavilion another area of tufa indicates the former presence of springs at a level higher than any now existing.

The thickness of the tufa deposit is likely to be overestimated, as it covers steep slopes and even cliff faces.

The earliest description of the place tells of its forming overhanging masses alongside the creek, whose flood waters swept away its support. The natural exposures of conglomerate and sandstone outcropping near the pavilion show that the tufa is there underlain by hard rock. Farther west, however, the tufa overlies soft, shaly rocks, which have been digested by the hot waters and vapors for so long a time that the material is as soft as ashes, and in the development of new water supplies near Spring No. 1 a pipe was driven 38 feet down into this material. Immediately beneath the tufa there is a breccia of novaculite sandstone or shale fragments cemented by iron oxide, manganese oxide, and carbonate of lime. This is seen under the tufa at the Cave spring and at the Dripping spring. It merely represents the old hillside débris cemented by the hot-water deposit and material deposited later beneath the tufa mantle.

The owners of the Hale bath house have cut a short tunnel into the tufa back of their establishment, and the natural heat of the ground is used for a vapor bath. There is no doubt that the ground back of Bath House Row is permeated by a network of fissures and is heated by hot-water vapors.

*Vegetation of tufa area.*—The tufa area is described by all earlier writers as being distinguished from the adjacent slope by its peculiar vegetation. In the improvement of the reservation this distinction has been largely obliterated, as flowers and shrubs have been freely planted. The tufa cliffs and rougher exposures show, however, the limestone-loving ferns *Cheilanthes alabamensis* Kunze and *Adiantum capillus-veneris* L., which occur nowhere else in this region. Owen mentions these ferns especially, besides numerous peculiar mosses and algæ, and the stonecrop, sage, lobelia, and senna as characteristic of the tufa area.

#### GEOLOGICAL RELATIONS OF THE HOT SPRINGS.

In the geological sketch already given the rocks from which the hot waters issue are described as sandstones and shales of Lower Silurian age, occurring in sharply compressed folds. The hot waters issue from the sandstones seen well exposed back of the superintendent's office and near the music pavilion, and from the overlying shales in the area west of the pavilion. These rocks form part of a steeply dipping anticline plunging beneath the surface toward the southwest. It may be compared to the partly buried prow of an upturned boat. The rocks arch around the mountain slopes, the different beds being revealed very much as the scales of an onion bulb are exposed when it is partly cut into. While the rocks are flexed into this great curve, the great and thick beds of hard sandstone and conglomerate were cracked while being flexed, and little slips and breaks occur. The smaller cracks form a network of fractures, which in some places are seen to be filled with white quartz. The map shows the principal springs to be arranged along a line running about NNE., or parallel to the axis of the fold



forming Hot Springs Mountain. This line is believed to be a fissure corresponding to a fracture of the northwest fold, a fault fissure. Springs are common along such fractures in the novaculite region of Arkansas, and there is no reason to believe there is anything unusual in this one. The source of heat is discussed elsewhere.

#### THE HOT SPRING WATERS.

The Hot Springs yield waters of remarkable purity. This, in fact, is the reason ascribed by some physicians for the efficacy of the water as a remedial agent. The very complete analyses given in this report show a very small amount of mineral matter. The purity of the natural waters of the region is well known. The water of the Happy Hollow spring has less mineral matter than any other of the waters known, except that of the Poland spring, of Maine. These waters rise through siliceous rocks, and the fact that the hot waters contain so little mineral matter, particularly silica, is evidence of their meteoric origin, and accords with the nature of the gases given off by the springs.

A direct comparison of the analyses with those made in earlier years is not possible, since the analyses are given in parts per million, while those of the State geological survey are in grains per gallon. I have recalculated the analyses of the larger springs, however, and find the analyses nearly identical, showing conclusively that the nature of the waters is not changing with time.

The accompanying table gives a recapitulation of the analyses made by Mr. J. K. Haywood, of the Bureau of Chemistry, Department of Agriculture.



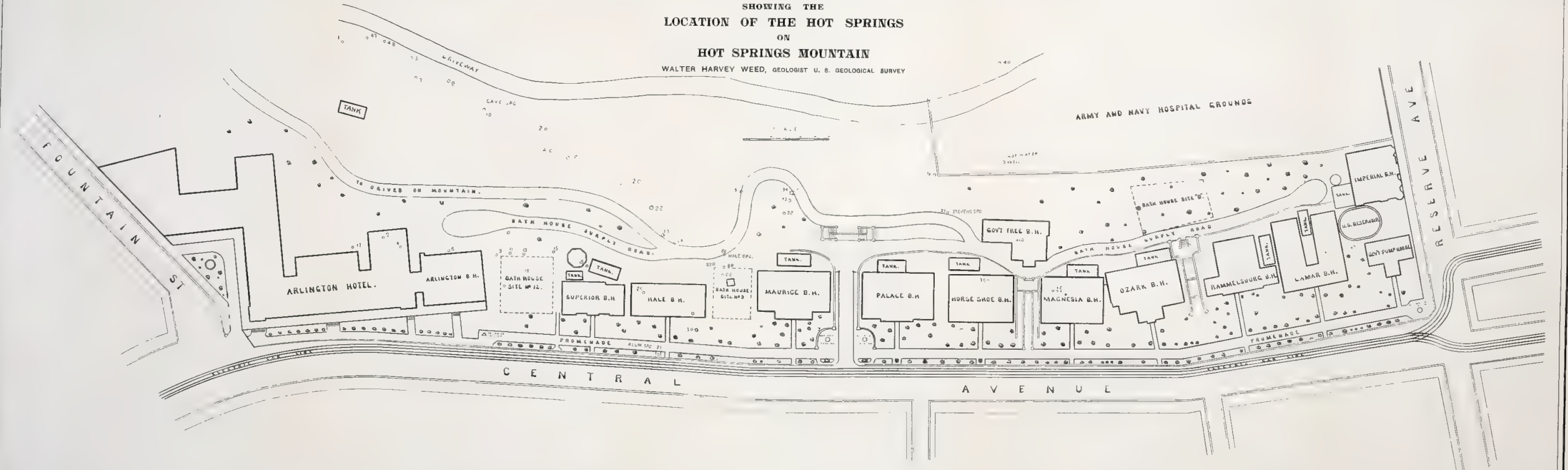




# BATH HOUSE PARK, HOT SPRINGS RESERVATION

SHOWING THE  
LOCATION OF THE HOT SPRINGS  
ON  
HOT SPRINGS MOUNTAIN

WALTER HARVEY WEED, GEOLOGIST U. S. GEOLOGICAL SURVEY





No.	Degrees Fahr.	Flow in gallons per 24 hours.	Total parts per million.	SiO <sub>2</sub> .	SO <sub>4</sub> .	HCO <sub>3</sub> .	NO <sub>3</sub> .	NO <sub>2</sub> .	PO <sub>4</sub> .	BO <sub>2</sub> .	AsO <sub>4</sub> .	Cl.	Br.	I.	FeAl.	Mn.	Ca.	Mg.	K.	Na.	Li.	NH <sub>4</sub> .
1	143.4	28,800	280.792	45.11	7.83	166.50	.88	Trace.	Trace.	(a)	None.	2.50	Trace.	Trace.	0.24	0.36	46.09	4.81	1.65	4.52	Trace.	0.302
2	129.0	10,800	272.310	44.48	8.24	160.50	.44	Trace.	Trace.	(a)	None.	2.50	Trace.	Trace.	.24	Trace.	44.64	4.77	1.98	4.46	Trace.	.060
3	143.1	19,938	279.6287	44.89	7.76	166.60	.007	.0007	Trace.	(a)	None.	2.50	Trace.	Trace.	.28	.22	44.36	4.78	1.65	4.52	Trace.	.02
4	132.6	3,600	271.8943	43.55	8.63	160.50	.44	.0013	Trace.	(a)	None.	2.38	Trace.	Trace.	.35	.22	44.61	4.68	2.01	4.48	Trace.	.043
5	143.4	17,280	279.3862	44.31	7.85	166.50	.44	.0022	Trace.	(a)	None.	2.38	Trace.	Trace.	.28	.22	46.58	4.58	1.65	4.51	Trace.	.084
6	136.9	32,400	277.5563	44.51	8.50	163.50	.75	.0013	Trace.	(a)	None.	2.75	Trace.	Trace.	.21	.18	46.25	4.88	1.68	4.50	Trace.	.025
7	141.4	18,514	284.9401	44.59	7.92	169.60	.33	.0041	Trace.	<sup>86</sup> (a)	None.	2.50	Trace.	Trace.	.35	.28	47.23	4.99	1.70	4.57	Trace.	.116
8	97.2	e18,000	289.4162	46.28	7.88	172.60	.22	.0012	Trace.	(a)	None.	2.50	Trace.	Trace.	.28	.11	48.35	4.90	1.80	4.54	Trace.	.065
9	144.3	e1,840	279.4533	44.91	7.60	166.50	.09	.0013	Trace.	(a)	None.	2.38	Trace.	Trace.	.21	.22	46.18	4.97	1.68	4.64	Trace.	.062
10	135.3	18,514	271.6026	44.55	7.73	160.50	.18	.0016	Trace.	(a)	None.	2.38	Trace.	Trace.	.21	.22	45.87	4.94	1.60	4.37	Trace.	.031
11	134.2	.....	275.0962	47.44	8.28	160.50	.18	.0012	Trace.	(a)	None.	2.71	Trace.	Trace.	.12	.11	43.84	4.98	1.66	5.18	Trace.	.095
12	97.2	524	170.0858	32.52	6.73	93.90	.18	.0008	.13	(a)	None.	2.43	Trace.	Trace.	.11	Trace.	25.89	3.18	1.31	3.68	Trace.	.025
13	133.3	.....	281.6642	46.17	7.85	166.50	.18	.0012	Trace.	(a)	None.	2.57	Trace.	Trace.	.11	.12	46.22	4.84	1.60	4.87	Trace.	.043
14	145.0	8,640	280.0113	45.17	7.95	166.50	.44	.0033	Trace.	(a)	None.	2.36	Trace.	Trace.	.11	.27	46.21	4.93	1.57	4.98	Trace.	.048
15	147.0	201,600	284.8016	45.59	7.84	168.10	.44	.0016	.05	1.29	None.	2.53	Trace.	Trace.	.19	.34	46.93	5.10	1.60	4.76	Trace.	.040
16	141.6	.....	274.6090	43.88	7.67	163.50	.27	.0010	Trace.	(a)	None.	2.36	Trace.	Trace.	.09	.29	45.50	4.81	1.60	4.61	Trace.	.028
17	133.5	.....	277.7790	45.67	8.58	163.50	.44	.0020	Trace.	(a)	None.	2.36	Trace.	Trace.	.09	Trace.	45.40	4.70	1.88	5.12	Trace.	.037
18	135.2	f35,000	279.4186	44.74	10.63	162.00	1.55	.0016	Trace.	(a)	None.	2.57	Trace.	Trace.	.09	Trace.	46.04	4.94	2.01	4.79	Trace.	.057
19	133.5	13,292	272.1120	44.35	8.75	159.00	1.33	.0010	Trace.	(a)	None.	2.57	Trace.	Trace.	.09	.11	47.42	4.71	2.00	4.58	Trace.	.011
20	115.3	3,677	231.0240	39.90	7.31	133.20	.31	.0010	.13	(a)	None.	2.43	Trace.	Trace.	.09	.11	37.43	4.23	1.47	4.40	Trace.	.013
21	114.8	1,152	280.9003	45.56	7.95	166.50	Trace.	.0013	Trace.	(a)	None.	2.57	Trace.	Trace.	.09	.11	45.97	4.84	1.65	5.59	Trace.	.069
22	134.8	1,723	273.3505	44.79	8.03	162.00	Trace.	.0055	Trace.	(a)	None.	2.43	Trace.	Trace.	.09	.18	44.73	4.82	1.74	5.11	Trace.	.025
23	144.3	e10,800	285.1230	46.25	7.97	169.60	Trace.	.0010	Trace.	(a)	None.	2.50	Trace.	Trace.	.09	.15	46.75	4.92	1.74	4.78	Trace.	.032
24	144.1	.....	284.8858	46.85	7.81	168.80	Trace.	.0008	Trace.	(a)	None.	2.83	Trace.	Trace.	.22	.29	46.82	5.01	1.69	4.73	Trace.	.035
25	144.8	f85,000	282.8687	47.31	7.80	166.50	Trace.	.0007	Trace.	(a)	None.	2.50	Trace.	Trace.	.19	.14	39.61	4.95	1.73	4.66	Trace.	.028
26	146.1	25,847	283.1718	47.86	7.82	166.50	Trace.	.0008	Trace.	(a)	None.	2.58	Trace.	Trace.	.19	.15	45.47	4.82	1.76	4.89	Trace.	.021
27	125.4	800	258.7180	49.95	7.98	146.70	.22	.0010	Trace.	(a)	None.	2.58	Trace.	Trace.	.16	.14	39.61	4.95	1.73	4.66	Trace.	.037
28	139.6	f21,000	280.4218	47.41	7.80	165.00	.27	.0008	Trace.	(a)	None.	2.58	Trace.	Trace.	.21	.15	45.97	4.80	1.76	4.89	Trace.	.061
29	136.0	2,618	282.0203	48.02	7.64	165.00	.22	.0003	.80	(a)	None.	2.58	Trace.	Trace.	.22	.15	45.97	4.80	1.67	5.09	Trace.	.010
30	129.0	(g)	273.7730	50.90	7.50	157.50	.44	.0020	Trace.	(a)	None.	2.67	Trace.	Trace.	.12	.25	43.00	4.92	1.72	4.99	Trace.	.011
31	124.5	b7,200	278.1828	47.40	8.78	162.00	.34	.0008	Trace.	(a)	None.	2.67	Trace.	Trace.	.19	.25	45.45	4.72	1.65	4.69	Trace.	.042
32	115.7	28,800	274.8743	48.27	8.29	159.00	.34	.0013	Trace.	(a)	None.	2.50	Trace.	Trace.	.19	.12	44.75	4.73	1.72	4.94	Trace.	.023
33	120.6	.....	283.1133	49.60	8.53	165.00	Trace.	.0013	Trace.	(a)	None.	2.50	Trace.	Trace.	.22	.15	45.94	4.80	1.68	4.65	Trace.	.042
34	118.2	28,800	278.4166	46.90	8.08	163.50	Trace.	.0016	Trace.	(a)	None.	2.67	Trace.	Trace.	.24	.04	45.68	4.73	1.69	4.84	Trace.	.045
35	109.4	2,469	280.7643	46.57	7.49	165.60	1.33	.0013	Trace.	(a)	None.	2.50	Trace.	Trace.	.19	.20	46.32	4.79	1.70	4.65	Trace.	.023
36	120.0	9,600	282.3637	48.84	8.71	163.50	.78	.0007	Trace.	(a)	None.	2.58	Trace.	Trace.	.19	.11	46.33	4.92	1.68	4.70	Trace.	.036
37	127.2	f40,000	296.9973	46.65	15.78	169.60	Trace.	.0013	Trace.	(a)	None.	2.67	Trace.	Trace.	.14	.08	49.93	5.07	1.76	5.28	Trace.	.030
38	139.6	f40,000	290.5305	49.81	7.86	171.10	Trace.	.0005	Trace.	(a)	None.	2.50	Trace.	Trace.	.26	.27	46.61	5.07	1.60	5.42	Trace.	.030
39	142.5	35,000	294.8740	50.51	9.41	163.50	1.33	.0030	Trace.	(a)	None.	3.33	Trace.	Trace.	.28	.14	47.11	5.14	1.93	5.98	Trace.	.111
40	120.0	4,320	276.8390	45.73	7.76	163.50	Trace.	.0010	Trace.	(a)	None.	3.17	Trace.	Trace.	.19	.19	45.43	4.96	1.59	5.00	Trace.	.008
41	118.9	f4,000	297.0996	52.30	11.95	168.10	.44	.0016	Trace.	(a)	None.	3.67	Trace.	Trace.	.29	.29	46.89	5.22	2.23	6.49	Trace.	.018
42	136.9	f50,000	286.1788	49.63	8.40	166.50	.44	.0008	Trace.	(a)	None.	2.83	Trace.	Trace.	.33	.07	45.93	5.19	1.72	5.08	Trace.	.058
43	115.3	f20,000	310.0393	43.21	28.67	160.50	.22	.0013	.53	(a)	None.	5.83	Trace.	Trace.	.44	None.	49.22	4.24	8.84	8.33	Trace.	.008
44	46.4	659	36.459	12.50	2.50	12.10	.89	Trace.	Trace.	(a)	None.	1.83	Trace.	Trace.	.34	Trace.	1.89	1.36	.94	2.10	Trace.	.009
45	55.4	511	437.817	15.06	2.29	15.14	.44	.0007	Trace.	(a)	None.	2.00	Trace.	Trace.	.34	Trace.	3.79	1.45	1.02	2.23	Trace.	.021
46	124.7	f25,000	284.77	49.16	8.21	166.50	(i)	(i)	.33	(a)	None.	2.50	Trace.	Trace.	.18	.21	45.79	5.06	1.57	5.26	Trace.	(i)

<sup>a</sup> Small amount. <sup>b</sup> Includes No. 17. <sup>c</sup> Includes No. 16. <sup>d</sup> Includes Nos. 11 and 13. <sup>e</sup> Includes No. 24. <sup>f</sup> Estimated. <sup>g</sup> Could not be estimated. <sup>h</sup> Includes No. 33. <sup>i</sup> Not determined.



*Gases.*—The gases given off by the hot waters were carefully collected and analyzed. The results show that they consist of carbon dioxide, oxygen, and nitrogen. The ratio of oxygen and nitrogen corresponds very closely to that of atmospheric air, and, taking into account the relative absorption of the two gases by water, there can be no doubt that the oxygen and nitrogen given off by the water come from absorbed air.

*Source of water.*—From what has already been said in discussing the geological and topographical relations of the springs, and from the composition of the water and of the gases, there seems no doubt that the hot springs correspond closely to the ordinary springs of the mountain region save in the very important element of heat. As will be shown later, it is believed that the waters of a very large but entirely normal spring, or springs, have been heated by vapors rising through fissures penetrating its unknown depths.

*Source of mineral contents.*—The mineral matter of the waters has come from the rocks traversed by the waters. Recollecting the solvent power of hot water, it is rather remarkable that the waters are so pure. The underlying rocks are Silurian sediments resting on an unknown complex, but the Silurian rocks alone are competent to supply all the mineral matter of the waters.

#### ARE THE HOT SPRINGS DYING?

The question whether the hot springs are changing in character and will eventually either cease flowing or become cold springs is of both popular and scientific interest. The evidence seems to show that there is a very small decrease in temperature since they were first examined, now nearly a century ago. The temperature recorded by Dunbar and Hunter in 1804 for the larger spring was  $150^{\circ}$  F., and another had a temperature of  $154^{\circ}$ . In 1859 the springs were carefully examined by David Dale Owen, State geologist, whose map of temperatures and elevations is reproduced in Plate VIII herewith. A more accurate map was published by William Glasgow, jr., in 1860 from careful instrumental surveys, together with records of temperature and outflow.

Since then many changes have been made about the springs, all of which have been dug out and inclosed in masonry arches, with the consolidation of two or more springs into one in some instances, the development of new outflows by digging wells or sinking pipes, and the drying up of adjacent natural outflows. For these reasons all the springs now existing can not be positively identified with those shown on the earlier maps, but a majority of them are so correlated without doubt.

*Temperatures.*—The comparison of the old records mentioned with those recently made shows that the highest temperature known to-day is  $147^{\circ}$  F., as against  $154^{\circ}$  in 1804, and  $150^{\circ}$  by Glasgow and  $148^{\circ}$  by Owen in 1860. In a number of springs there is a decline of  $2^{\circ}$  since the latter date. Such a slight difference might, however, be due to differences in the manner or place of taking the temperatures, or the instruments used in the earlier years may not have been accurate. It is noteworthy that Owen's highest temperature, taken in 1859 with a standardized thermometer, was  $148^{\circ}$ , and that recorded now is  $147^{\circ}$ . In other words, the temperature is decreasing so slowly that the change

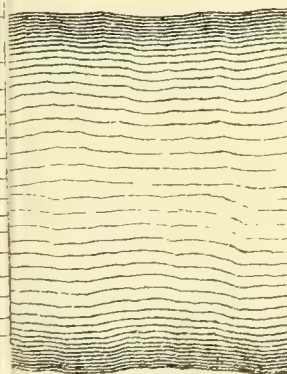
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*Temperatures in Ar  
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r State Geologist.*

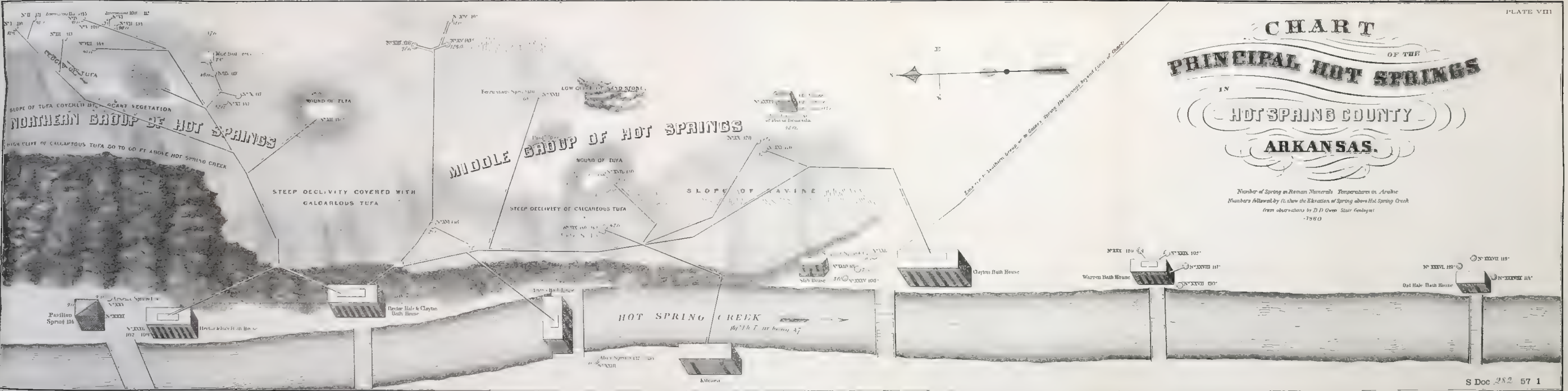






# CHART OF THE PRINCIPAL HOT SPRINGS IN HOT SPRING COUNTY ARKANSAS.

Number of Spring in Roman Numerals Temperature in Arabic  
Numbers followed by ft. show the Elevation of Spring above Hot Spring Creek  
from observations by D. D. Owen State Geologist  
-1980





is almost imperceptible in half a century. In one instance, that of the Alum spring, there is a very marked decrease in temperature, and as this is the only spring on the west side of the creek, there is no doubt of its identity. In 1804 this had a temperature of  $132^{\circ}$ . In 1859 its temperature was  $133^{\circ}$ , according to Owen, and to-day it is but  $114.8^{\circ}$ .

*Amount of outflow.*—The comparison of outflow is more difficult. According to Dunbar and Hunter the largest spring had an outflow of 11 quarts in eleven seconds in 1804, corresponding to 22,100 gallons per day, and the four largest springs had an outflow of 165 gallons per minute, or 237,600 gallons per day. Dr. Owen gives no measurements, but Glasgow gives the discharge of each spring—a total of 317 gallons per minute, or 450,480 gallons per day, as compared with 850,000 gallons per day at the present time. As the writer has shown elsewhere, the spring water is of meteoric origin, like most spring water, and probably varies somewhat from year to year, corresponding to variation in annual rainfall at some previous year, so that no definite comparison can be made with the early records, except to state that the volume of water discharged is very much greater. Supposing a practically constant amount of heat applied, this of itself would mean a slightly lowered temperature. In this connection attention should be called to the well put down by Major Torney, U. S. Army, in the Army and Navy Hospital, which is capable of yielding the amazing amount of 350,000 gallons per day without affecting but one very small spring (No. 40 of the list).

From a consideration of all these facts it is concluded that the springs are losing their heat so slowly that the loss is almost inappreciable.

*Amount of mineral matter carried in solution by the waters.*—No essential difference in the composition of the waters can be detected by a comparison of the analyses made for Owen or Larkin (1859) or for Dr. Branner, of the State geological survey, in 1889, with the elaborate and careful analyses made by the National Government. The waters are remarkable more for their purity than for their mineral contents. The material in solution consists mainly of bicarbonate of lime, which is so easily precipitated by the loss of carbonic acid gas that a deposit forms in pipes, and rather rapidly where the spring waters drip, as in the walls about the bowl of the Cave spring. The total mineral matter for all the springs amounts to 1,367 pounds a day, equivalent to 249.5 tons a year. This amount of material carried by the hot water from the earth's interior to the surface must leave a very considerable cavity in the course of time.

#### SOURCE OF HEAT.

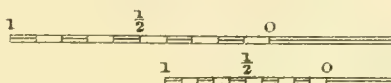
While there have been many theories advanced to account for the source of the hot waters, the only hypothesis that stands the test of scientific inquiry is the one which ascribes the heat of the waters to still hot but concealed bodies of igneous rock. It seems scarcely necessary to call attention to the absurdity of the idea that either slaking lime in the depths of the earth or chemical reaction of the waters with the atmosphere could be the cause of the heat. That the waters come from a depth sufficient for their heating by the normal increment of earth heat ( $1^{\circ}$  for every 50 feet) seems unreasonable, since it would necessitate a depth of nearly 5,000 feet to give the waters their present temperature, even assuming that they were not cooled in their course



upward. The composition of the gases given off by the waters shows that they contain atmospheric air as well as carbon dioxide. That the heat of the waters is due to the heat developed by the folding of the rocks, which is the theory given to account for the heat at the Virginia Hot Springs, is not probable, for the folding at Hot Springs is not more intense than elsewhere in the mountain regions of Arkansas, and no evidence of hot spring action has been found at any other localities except where igneous rocks are present.

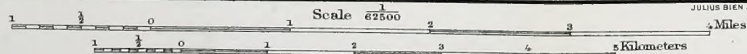
It is believed that the heat comes from a great body of still heated igneous rocks intruded in the earth's crust by volcanic agencies and underlying a large part of central Arkansas. The existence of such a mass is shown by the great bodies of granite seen at Potash Sulphur Springs and Magnet Cove, where the rocks have been exposed by the wearing down of the overlying sediments, though the igneous rocks seen were of course long since cooled. At Magnet Cove, moreover, there are tufa deposits which show the former occurrence of hot springs.

This hypothesis is strengthened by the occurrence of intrusive dikes at various localities about the springs, and their trend and occurrence indicate that the molten material which filled the fissures did not come from the bodies of rock now exposed at Potash Sulphur Springs or at Magnet Cove, but had some deep-seated source, whose location is indicated by the dikes as being approximately under the hot springs. Deep-seated waters converted into vapors by contact with this "batholith" of hot rock probably ascend through fissures toward the surface, where they probably meet cold spring waters which are heated by the vapors. As the igneous dikes near by are fissures reaching down to this great mass of igneous magma which have been filled by it to form dikes, it is not unreasonable to suppose that fissures extend down to the now solid but still hot igneous mass.



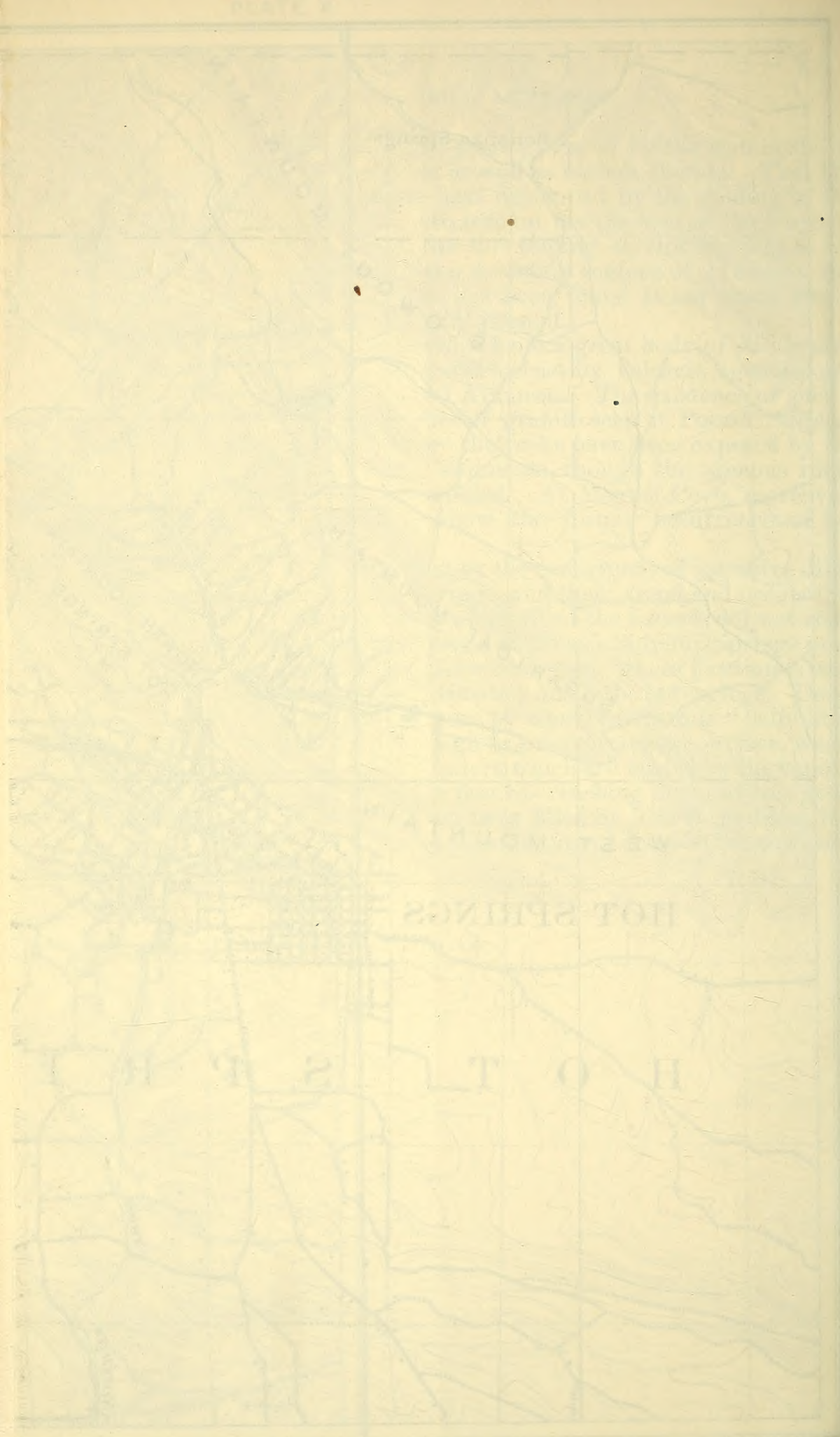






Contour interval 20 feet.  
Datum is mean sea level.

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